MICHIGAN STATE
UNIVERSITY

ENERGY TRANSITION PLAN

JANUARY 2012

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POWERING THE FUTURE

Every day at Michigan State University, 17,000 on-campus residents wake up to electrical alarm clocks, turn on their televisions and computers, take showers and brush their teeth, eat food cooked in the dining halls, and attend lit and heated or cooled classrooms with another 30,000 of their peers. Faculty and students conduct life-altering and world-renowned research in climate-controlled, heavily powered labs.

To make all this happen, the T.B. Simon Power Plant has been the chief power provider to the 5,200-acre university with more than 47,000 students, 13,000 employees and over 550 instructional, research and residential buildings. It has served MSU well since it was built in 1965, giving one of the nation's largest universities a reliable and independent power source – able even to keep the university humming during the 2003 blackout that knocked out power to 50 million people in northeastern United States and parts of Canada.

But one of the greatest challenges for MSU is how to reliably meet the university's growing energy needs while reducing negative impacts of power generation on our environment. MSU's utility budget for FY 2011 was $80 million and energy costs are on the rise. If current growth trends continue, MSU's power plant is expected to reach its capacity for steam in 2018 and electricity in 2039. Furthermore, federal and state air quality and emissions legislation is quickly progressing, which will require capital expenditures and constrain fuel choices.

We know that in the long-term, fossil fuel sources either will no longer be available or will be too costly to use.

Power is not optional. How we generate and use it is.

Now is the time for MSU to adopt a complete long-term Energy Transition Plan preparing for a renewable energy future.

EXECUTIVE SUMMARY

Being bold is not about baby steps. It requires imagination, unconventional thought and courage – attributes forged and flourished at esteemed institutions such as Michigan State University.

With this as its driving force, MSU since 2006 has cut its coal consumption by 28%, and dropped its energy use per square foot by 9.5%, while releasing 6% less greenhouse gases into our atmosphere between 2000 and 2010.

These accomplishments should be lauded, but they are not bold enough.

Challenges to our environment, health, and infrastructure force us to do better. Rising energy costs and emerging government regulations influence our bottom line and the way we do business. Our power plant continues to release harmful emissions that affect our environment and health. At the same time, we must reliably meet energy needs of an ever-expanding campus.

We need a change.

As world leaders in public research with a clear financial and personal stake in the quality of our own environment, MSU has long desired to transition to cleaner, more renewable energy. In 2009, the university set out to create a long-range plan to transition out of using fossil fuels and into more sustainable energy sources. It took time to carefully develop the best possible plan utilizing all available knowledge, technology and resources. Meanwhile, we have made strides to diversify our energy sources and build our capacity for renewable energy.

Now we are ready. With extensive input from experts inside and outside of the university, as well as from the MSU and surrounding community, the Energy Transition Plan Steering Committee has crafted an Energy Transition Plan to accelerate efforts and move the university into a sustainable future.

THE ULTIMATE GOAL: 100% RENEWABLE ENERGY

Can this happen overnight? No. It will take time. It will take a commitment of the MSU community to work together. It will take investments of resources and realigning of priorities. It will take more advanced technology than currently available. But this is the first and most important step toward a renewable future at MSU. If adopted by the Board of Trustees, this plan will set standards and govern future energy decisions, similar to how the Campus Master Plan guides the university's growth. By design, this plan sets high-level goals and recommends strategies that will meet the energy needs of the campus, reduce carbon emissions, and implement renewable energy infrastructure. This will be a university-wide effort with far-reaching benefits to improve the world for many generations.

We look forward to working with everyone to achieve our shared goal for a better future.

A NECESSARY TRANSITION

As a premier public research university for over 150 years, MSU has had a mission to advance knowledge and transform lives through high-impact, innovative teaching, research and outreach activities. What better way to grow our World-grant mission and demonstrate our commitment to answer questions and create solutions for our nation's and the world's most pressing problems – climate change, energy supply and demand, the health effects of air pollution, and environmental sustainability – than by crafting an innovative, cost-effective Energy Transition Plan to guide us into a sustainable future?

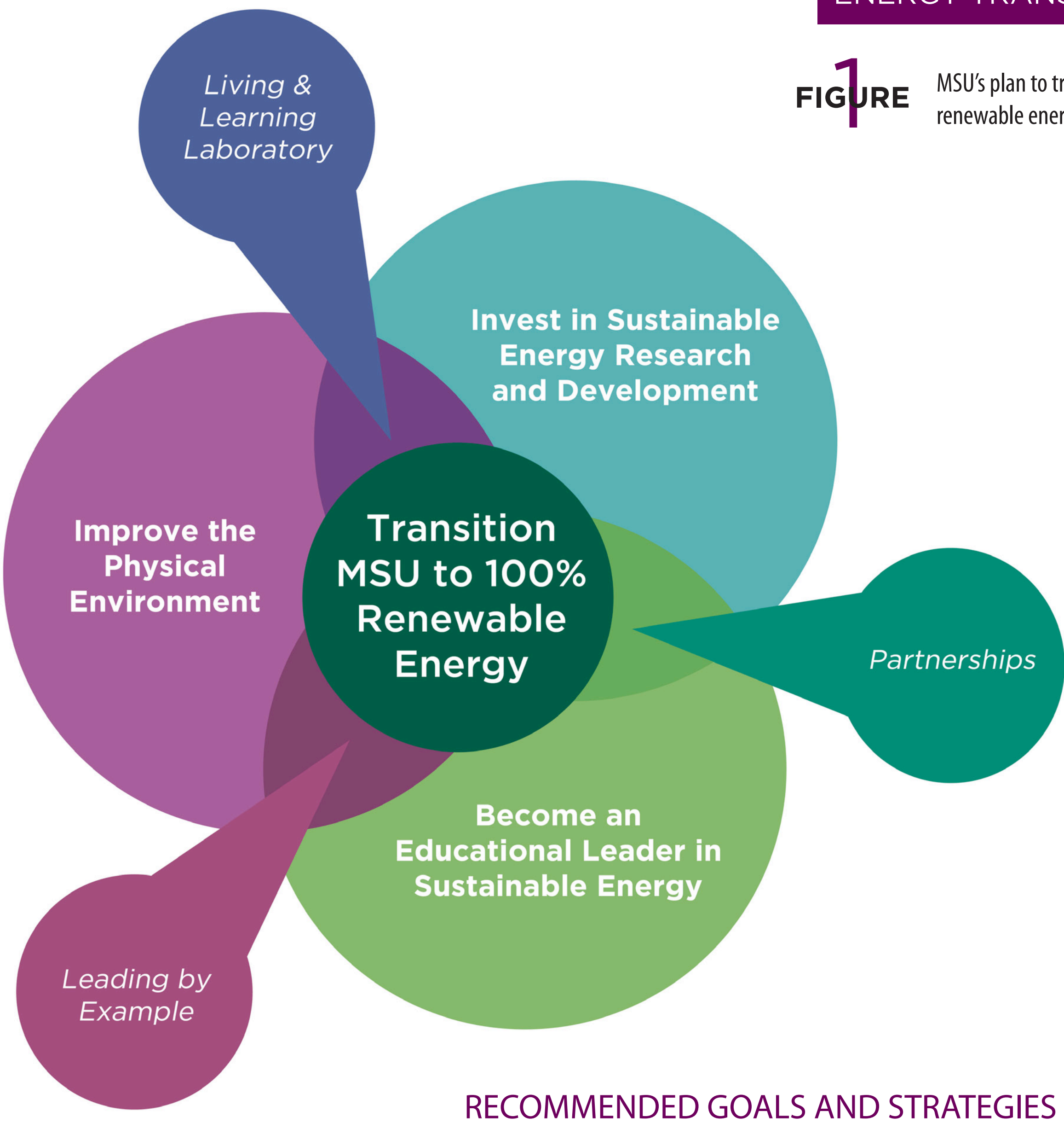
Furthermore, MSU is facing some unavoidable realities that necessitate such a change. MSU's power plant is expected to reach its current capacity for steam in 2018 and electricity in 2039. Meanwhile, federal and state air quality and emissions legislation is quickly progressing, which will require capital expenditures and constrain fuel choices.

Fueled by President Lou Anna K. Simon's Boldness by Design strategic imperative introduced in 2005, the long-range Energy Transition Plan will meet the growing needs of the campus and allow the university to adapt to changing technologies, regulations and resources.

The plan was built upon MSU's successful model of engaging the campus community for solutions to the university's energy challenges. The Energy Transition Plan Steering Committee, a diverse group of 24 faculty, staff and students representing a variety of viewpoints and expertise, reached out to those involved in the MSU Beyond Coal and Greenpeace student groups, as well as the broader student population and surrounding community to ensure robust discussion and inclusion of many viewpoints. Simultaneously, an external advisory group comprised of industry experts reviewed the plan at critical steps to ensure its viability.

The plan utilizes solid data and research from MSU faculty, students and staff as well as outside experts, and addresses critical variables – reliability, cost, health, environment, and capacity – that impact MSU's many stakeholders in the proximate community, across the state, and throughout the world.

FIGURE 1 MSU's plan to transition to 100% renewable energy



RECOMMENDED GOALS AND STRATEGIES

The Energy Transition Steering Committee recommends that the university set a bold vision for moving toward 100% renewable energy sources.

GOAL 1

IMPROVE THE PHYSICAL ENVIRONMENT

MSU cannot continue business as usual. While it is not yet feasible today to use 100% renewable energy due to a lack of cost effective and reliable alternative energy technologies, we must establish targets that continuously increase the amount of renewable energy used on campus. Today, renewable energy makes up less than 2% of the energy mix at MSU. Furthermore, lowering greenhouse gas emissions will reduce negative impacts to the environment and to health, as well as mitigate the financial risk of potential greenhouse gas legislation. Based on the options modeled and discussed with the committee and the community, the following targets (from a baseline year of Fiscal

FIGURE 2 MSU's plan for their transition to 100% renewable energy

	% Campus Renewable Energy	% Greenhouse Gas Emission Reduction
FY 2015	15	30
FY 2020	20	45
FY 2025	25	55
FY 2030	40	65

Year 2009-10) are considered to be both aggressive and achievable with the knowledge and resources available today:

These targets are set based on consideration of projected campus growth and energy needs, and a number of alternatives in terms of available and emerging technologies, cost effectiveness, reliability and implications for MSU's cost structure. The targets that are set maintain a reliable energy system, meet capacity and push out the need for additional capacity beyond 2050, and reduce emissions that negatively impact health and the environment.

Recommended Strategies:

- **Pursue aggressive, sustainable energy conservation and re-invest energy savings for future energy needs**
- **Implement a smart growth strategy to minimize the amount of new square footage added to the campus**
- **Create a system that connects energy and space costs and incentives to end users**
- **Implement more aggressive building energy standards**
- **Continue to monitor and improve energy efficiency standards**
- **Maximize switching to alternative cleaner fuels (subject to availability, technical and regulatory constraints)**
- **Implement smart-grid technology**
- **Purchase green power**
- **Create large-scale renewable projects**
- **Utilize carbon offsets**
- **Educate the community on MSU's energy system and continue behavior change for energy conservation**

The committee recommends that the university prioritize energy conservation activities in order to reduce overall energy demand, and provide resources to invest in fuel switching to lower the carbon footprint and renewable energy infrastructure. In the short term, natural gas is the best candidate for fuel switching because of its compatibility with existing power plant boilers, and it emits 45% less carbon dioxide than coal. Immediately switching to more natural gas will reduce the university's carbon footprint and deleterious health emissions. In addition, renewable energy will mainly come from using more biomass at the power plant and purchasing green energy (electricity) from utility providers.

GOAL 2

INVEST IN SUSTAINABLE ENERGY RESEARCH AND DEVELOPMENT

The renewable energy and greenhouse gas emission targets in this plan assume that not only will new energy technologies become available in the future, but also that MSU will contribute actively to the development and demonstration of these new technologies. Sustainable energy will therefore become an integral component of the Boldness by Design initiatives and the Land-grant/World-grant mission. The combination of world-class researchers, energy infrastructure, and involved student body provides an ideal opportunity for the university to assume such a leadership role in sustainable energy systems research.

Recommended Strategies:

- **Promote sustainable energy research by using the campus as a living, learning laboratory for developing, evaluating and demonstrating new technologies**
- **Build on well-recognized, sustainable energy research programs by aggressively seeking expertise and sources of funding**
- **Systematically invest a portion of energy costs and cost savings in sustainable energy demonstration projects on campus**
- **Streamline facilities, policies and systems to enhance cross-disciplinary, cross-functional collaboration among academic units, faculty, staff and students**

GOAL 3

BECOME AN EDUCATIONAL LEADER IN SUSTAINABLE ENERGY

A Land-grant university has a mission beyond educating students and developing research. It also plays an important role in applying its knowledge to improve the quality of life for its local, regional and national communities. As we move toward our goal of renewable energy on campus, we have a responsibility to communities to share our process and lessons learned.

Recommended Strategies:

- **Educate stakeholders about MSU's longstanding commitment to and ongoing research in sustainable energy**
- **Share MSU's energy transition process and lessons learned from it**

COSTS

MSU has limited resources, so it is important to make strategic investments in energy to meet our long-term goals.

The Integrated Energy Planning Model, a model developed specifically for MSU to understand the impact of energy strategies, allowed the committee to consider multiple scenarios to evaluate emissions and renewable energy targets that were aggressive and achievable while staying within parameters for reliability, cost, and capacity. Several scenarios were considered, but the optimal scenario reduced the university's negative environmental and health impacts, while capturing energy savings that can be used for further conservation and renewable energy infrastructure.

Taking the steps toward a 100% renewable goal will require an investment. Based on the model, an investment of $30 to $40 million in energy conservation measures over the next 10 years, as well as increased investments per square foot of new construction to meet more stringent energy related building standards, will be required in order to meet the targets. When fully implemented, these investments are expected to yield an estimated 15% to 25% reduction in the average annual costs of utilities relative to the business-as-usual case. These savings then must be re-invested into other energy-related activities such as implementing additional conservation measures, funding the increase in fuel costs for fuel switching, and adding renewable energy to campus.

In addition, action now positions MSU to avoid significant costs and risks expected under possible future regulatory and legislative scenarios designed to place a price on greenhouse gas emissions or the use of fossil fuels for the production of energy. Projecting out through 2050, the Integrated Energy Planning Model shows MSU could save an estimated $200 million to $250 million in potential costs levied on greenhouse gas emissions due to reduced financial exposure.

More precise costs for the plan in its entirety cannot be calculated at this time because it is incumbent upon the Administration to determine the explicit course of action to take based on recommendations proposed in the Energy Transition Plan. The estimated costs detailed above fall mainly under Goal 1, which contains operational strategies. The majority of the costs come from accelerating energy conservation measures and energy efficient retrofits. Actual costs may differ from the estimates due to price fluctuations for consumables and durable goods such as fuel and equipment. Multiple funding strategies should be considered to finance implementation of the Energy Transition Plan, including traditional financing tools (cash reserves, debt capacity, and development funds), as well as partnerships, third party agreements, grants and other sources.

During implementation, the Administration should ensure that campus units still can fulfill their missions while implementing strategies at a department and program level, taking into account their size, ability to generate funds, etc.

IMPLEMENTATION AND REPORTING

Although informed by technical knowledge, the Energy Transition Plan does not dictate the specific operational decisions to be made to reach the goals. Those decisions must be carried out by the MSU Administration who will be responsible for meeting the goals and reporting on MSU's progress.

Upon acceptance of this plan by the Board of Trustees, MSU should take immediate action to implement a mix of strategies to meet the goals. Collaborative and inclusive teams of students, faculty and staff should be engaged to make sure these recommendations are successfully implemented. Progress toward these goals should be reported annually to the Board of Trustees and the MSU community.

The Energy Transition Plan should be dynamic in order to be relevant throughout technological, regulatory and environmental change. The committee recommends that this be a living document and reviewed every five years by a diverse university committee including students, faculty and staff. During the review, if MSU can move more aggressively toward its vision of 100% renewable energy, it should re-align its goals and targets accordingly.

NEXT STEPS

The committee recognizes that to accelerate reductions and achieve our recommended short-term and long-term goals, the MSU Administration will have to make a number of decisions with serious considerations of potential financial impact. Therefore, the university will have to define its priorities and carefully assess its options and trade-offs to accelerate our progress toward environmentally friendly and responsible policies, practices, systems and facilities. Cost-effective, available and emerging technology will necessarily play an important role in this process. Long-term sustainability should factor into all of these decisions.

The committee hopes that the flexibility of its recommendations in this plan will help to mitigate the financial risk of energy price fluctuations and currently known potential greenhouse gas legislation, and will move MSU toward a renewable energy future – providing a better future for MSU, its community and the world.

SHAPING THE FUTURE
THROUGH NECESSARY CHANGE

Climate change, energy supply and demand, the health effects of air pollution and environmental sustainability are among the most complex and urgent issues facing our world today.

As a premier Land-grant public research university for over 150 years, MSU has had a mission to advance knowledge and transform lives through high-impact, innovative teaching, research and outreach activities.

The university has made significant strategic investments in interdisciplinary research in bio-economy and energy, food and sustainability, the environment and health, and education. With this plan comes the opportunity for MSU to grow its reputation as a national and global leader among universities and expand our Land-grant to World-grant mission by demonstrating our commitment to answer questions and create solutions for the world's most pressing problems with an innovative, cost-effective Energy Transition Plan to guide us into a sustainable future.

President Lou Anna K. Simon provided the catalyst for the most recent energy work with her Boldness by Design strategic imperative in 2005, calling upon the campus community to create transformational change. Through it was born the Environmental Stewardship Initiative with energy as a key cornerstone. As a result, faculty, staff and students engaged in research and pilot programs to decrease energy use, reduce greenhouse gas (GHG) emissions, and provide the background data for our current energy transition efforts.

By 2009, MSU determined that it needed a long-range Energy Transition Plan to meet the growing needs of the campus and changing technologies and regulations. Business as usual would not be sufficient. Rising energy costs would force expensive retrofits to the current mechanical system and would put upward pressure on tuition and required capital. Air emissions impact the environment and public health, as well as potentially put the university at higher financial risk under regulatory changes being debated at the federal level. Furthermore, as a Land-Grant/ World-Grant institution, MSU had to operate its energy system in the most sustainable way possible. The campus had made progress, but changes and improvements needed to be faster and more significant to successfully weather these energy challenges.

A LIFELONG COMMITTMENT

While this timeline represents only the past two decades, Michigan State University has long been dedicated to sustainability and prudent energy use.

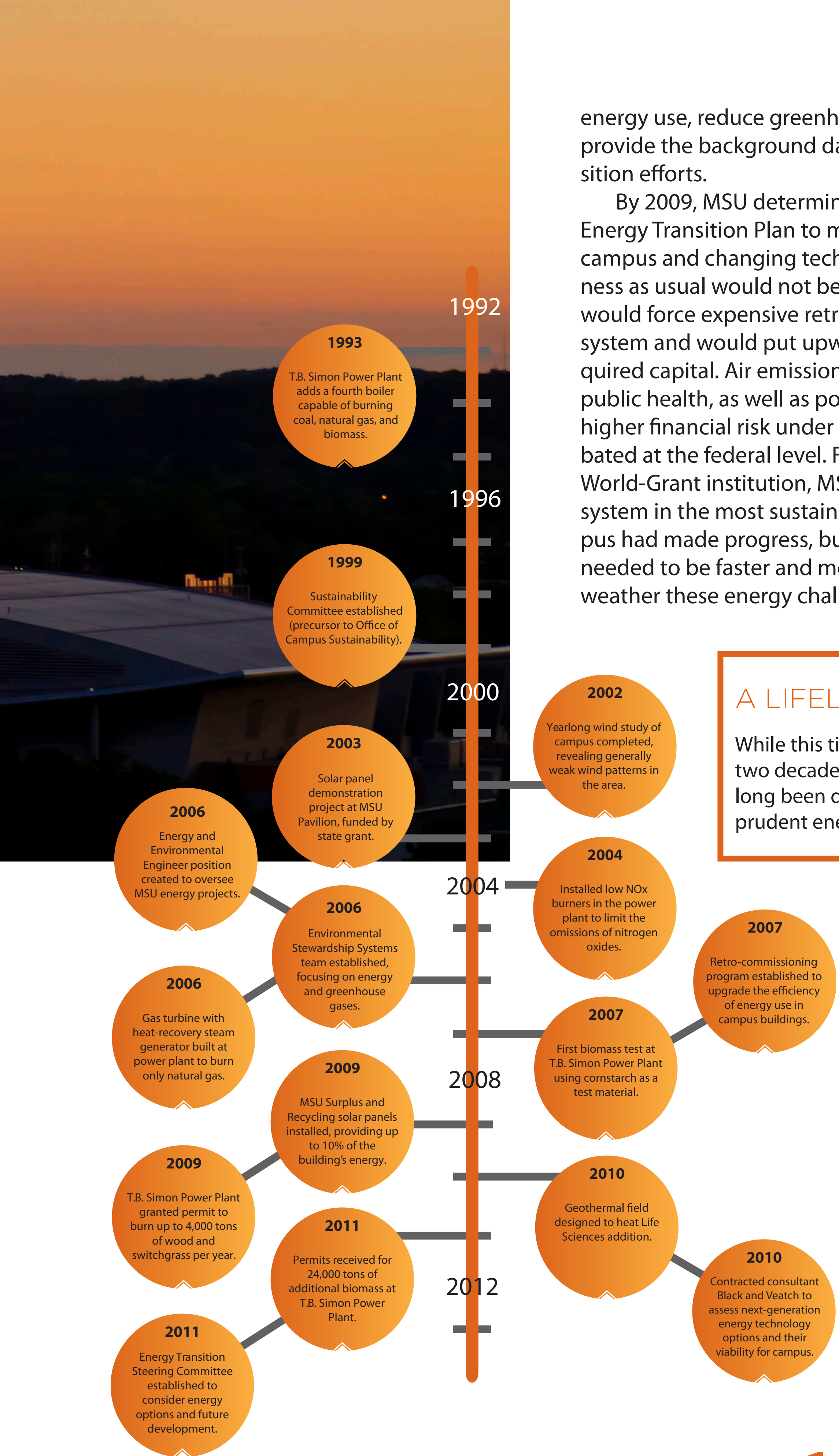


FIGURE 1 A history of energy initiatives at MSU

FIGURE 2 Modeling session user interface. Users were asked to meet capacity requirements by choosing a combination of efficiency and energy supply options.

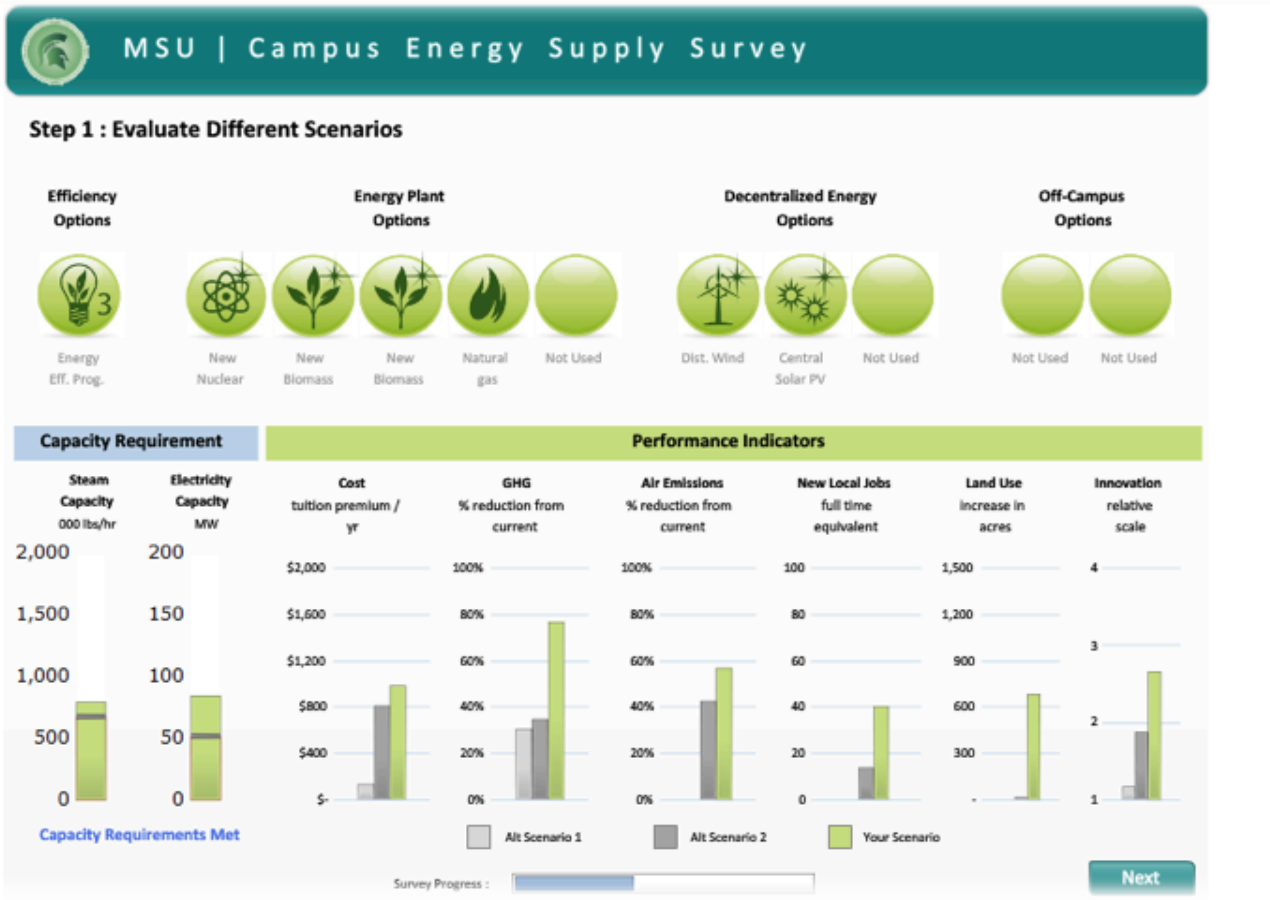
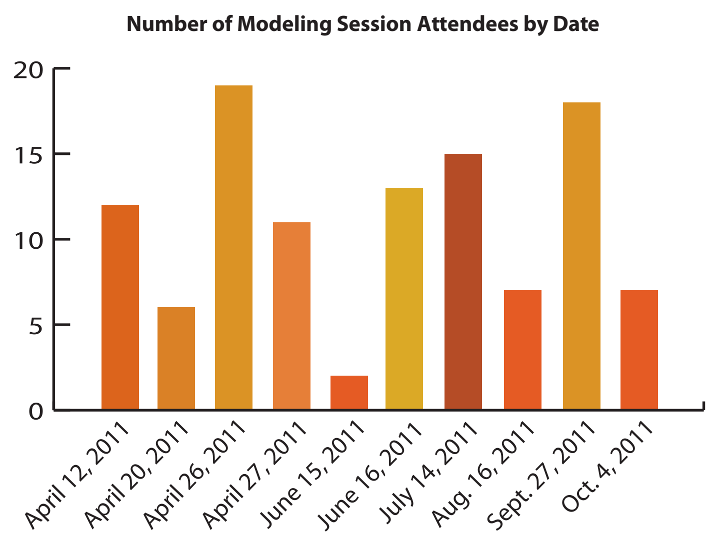


FIGURE 3 Modeling Session and Town Hall Attendees



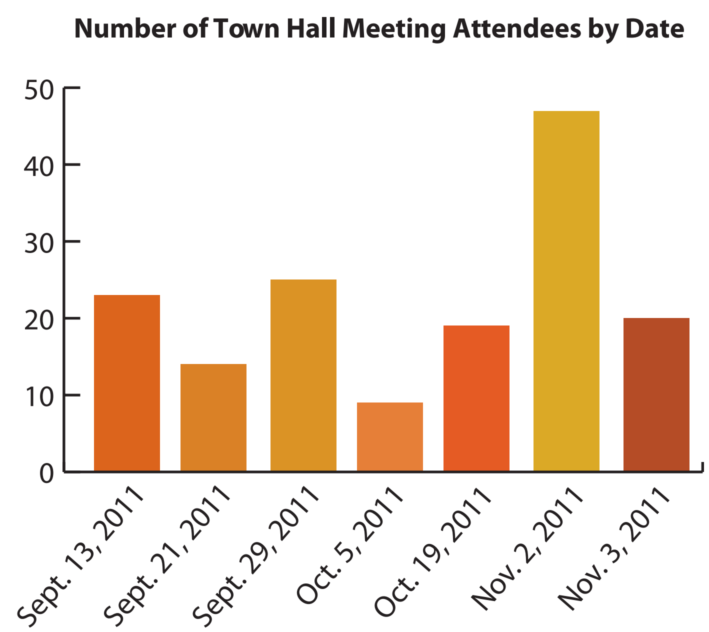


FIGURE 4 Participants at one of seven Town Hall forums review the plan and offer feedback.

The plan needed to be built upon MSU's successful model of engaging the campus community for solutions to MSU's energy challenges, and needed to address critical variables – reliability, cost, health, environment, and capacity – that impact MSU's many stakeholders in the proximate community, across the state, and throughout the world.

CREATING THE ENERGY TRANSITION PLAN

Developing a long-range energy plan for MSU needed to be deliberate, diverse, and dynamic. It needed to:

1. **Be built on solid research and MSU-specific data produced by the university's world-class faculty and researchers, and external energy experts.**

2. **Include robust discussion and inclusion of many viewpoints.**

3. **Allow for future changes in emerging technologies and regulations, available resources, and the latest research.**

The formal process to establish the Energy Transition Plan began in 2010, with staff and administrators collecting data, creating educational and financial models, and commissioning an independent study to evaluate MSU's energy infrastructure and emerging technologies.

Consultant Black and Veatch assessed MSU's power infrastructure and emerging technologies, and consultant Energy Strategies, LLC developed a model that integrated energy options with financial, environmental, health, capacity, and efficiency performance indicators.

By January 2011, an Energy Transition Plan Steering Committee was created and charged with the goal of creating the new energy plan. The Administration believed that the solution was likely moving toward renewable energy, and as such the plan should take steps to prepare MSU for a renewable energy future. The committee included a diverse group of 24 faculty, staff and students representing a variety of viewpoints and expertise. The Administration reached out to students involved in the MSU Beyond Coal and Greenpeace student groups, as well as the broader student population and surrounding community to ensure robust discussion and inclusion of many viewpoints. Simultaneously,

FIGURE 5 The Energy Transition Plan website made the planning process and resources transparent to the public.

an external advisory group comprised of industry experts reviewed the plan at critical steps to ensure its viability.

The committee integrated information from the consultants and internal researchers with the previously developed background information on MSU's current energy infrastructure, and projected demand growth by using the comprehensive modeling software program developed to analyze potential future scenarios.

After establishing assumptions, the committee brainstormed strategies to reduce energy use, GHG emissions and health effects. The strategies were modeled and through this process, physical goals were established. These goals were presented to the MSU and surrounding communities for public input. In addition, the Administration sought external opinions from those with experience in energy planning for higher education, energy regulation, and renewable energy technology and markets.

Other viewpoints were sought through aggressive outreach, including a series of 10 public modeling sessions to engage the community, seven town hall meetings to share the goals and strategies and allow for feedback, and through online comment forms available on a website dedicated for this project. In all, 110 people attended the facilitated educational modeling sessions where they were able to use an interactive program to design the MSU energy system of the future and then answer questions to determine which factors were most important to them. Another 157 people attended the town hall forums, and the committee also received feedback on the plan through the receipt of seven email forms and five comment cards. This feedback allowed the committee to add to and refine the goals and strategies.

Transparency and inclusion in all aspects of the planning process were key factors in the plan's development and were achieved through these outreach tools as well as documenting the process online, posting of all steering committee meeting notes online, and allowing people the opportunity to provide feedback at all points during the process.

The three-pronged plan presented in this report outlines strategies for physical changes of energy sources and modifications, leadership in outreach and engagement, and more cutting-edge research to guide the university and world in energy transitions. It does so while accounting for the five main challenges of capacity, cost, reliability, health, and environment.

If adopted, the Energy Transition Plan will guide future energy decisions for the university through 2030, much the way that the 2020 Campus Master Plan has guided the development of the campus. Like the Campus Master Plan, the Energy Transition Plan will be reviewed, updated and adjusted every five years extending the life of this plan beyond 2030.

POWERING MSU NOW

During its early years, the T.B. Simon Power Plant utilized the most advanced technologies available for a power plant of its size and purpose to serve the majority of the large and sprawling MSU campus.

The cogeneration of steam and electricity from a common fuel source is a thermodynamically efficient use of fuel and one of the most cost-effective methods of reducing carbon emissions of heating in cold climates. Cogeneration, or combined heat and power, captures heat created while generating electricity for 90% of the main campus, and rather than simply releasing it into the air, puts it to good use as pressurized steam to warm and cool the buildings. Underground steam tunnels distribute the heat and electricity, significantly reducing the risk of outages due to weather.

The common fuel source is usually coal, but emergence of research in the past two decades showing the harmful by-products of burning coal led MSU to adopt the practice of burning more natural gas and biofuel, and incorporating equipment to reduce emissions. In 2011 MSU increased the amount of natural gas used in the boilers. Natural gas emits about 45% less carbon dioxide than coal, thus contributing to the 9% decrease in GHG emissions from 2009 to 2010. Biomass use is restricted by government limits capping the amount of biofuel MSU is allowed to burn. The power plant in November 2011 was granted a permit to increase the amount of biofuel burned to 30% in boiler 4 and 5% in boilers 1, 2 and 3. The previous cap was 10% in boiler 4.

Operators also carefully monitor the cost of natural gas and purchase when prices are low to accommodate the university's budget. These fuel-switching strategies have reduced the plant's reliance on coal by 28% since 2006 and have helped decrease GHG emissions 6% between 2000 and 2010, and 9% between 2009 and 2010, a particularly noteworthy accomplishment given the university's addition of 2 million square feet of building space since 2000.
The power plant also has been purchasing electricity off-peak through an interconnection to the local utility to increase plant efficiency.

While the T.B. Simon Power Plant is a major part of the campus energy infrastructure, it is not the only source of on-campus energy. Renewable energy accounts for less than 2% of campus power, but MSU has been working on expanding renewable energy resources. As space has been renovated or constructed at MSU, the university has taken advantage of opportunities to incorporate renewable energy to help reduce GHG emissions and energy demand on the power plant.

The MSU Surplus Store and Recycling Center is fitted with solar panels that generate up to 10% of the building's electrical energy. Further, MSU is constructing its first geothermal system to heat and cool the Bott Building for Nursing Education and Research.

FIGURE 1 How the T.B. Simon cogeneration power plant works

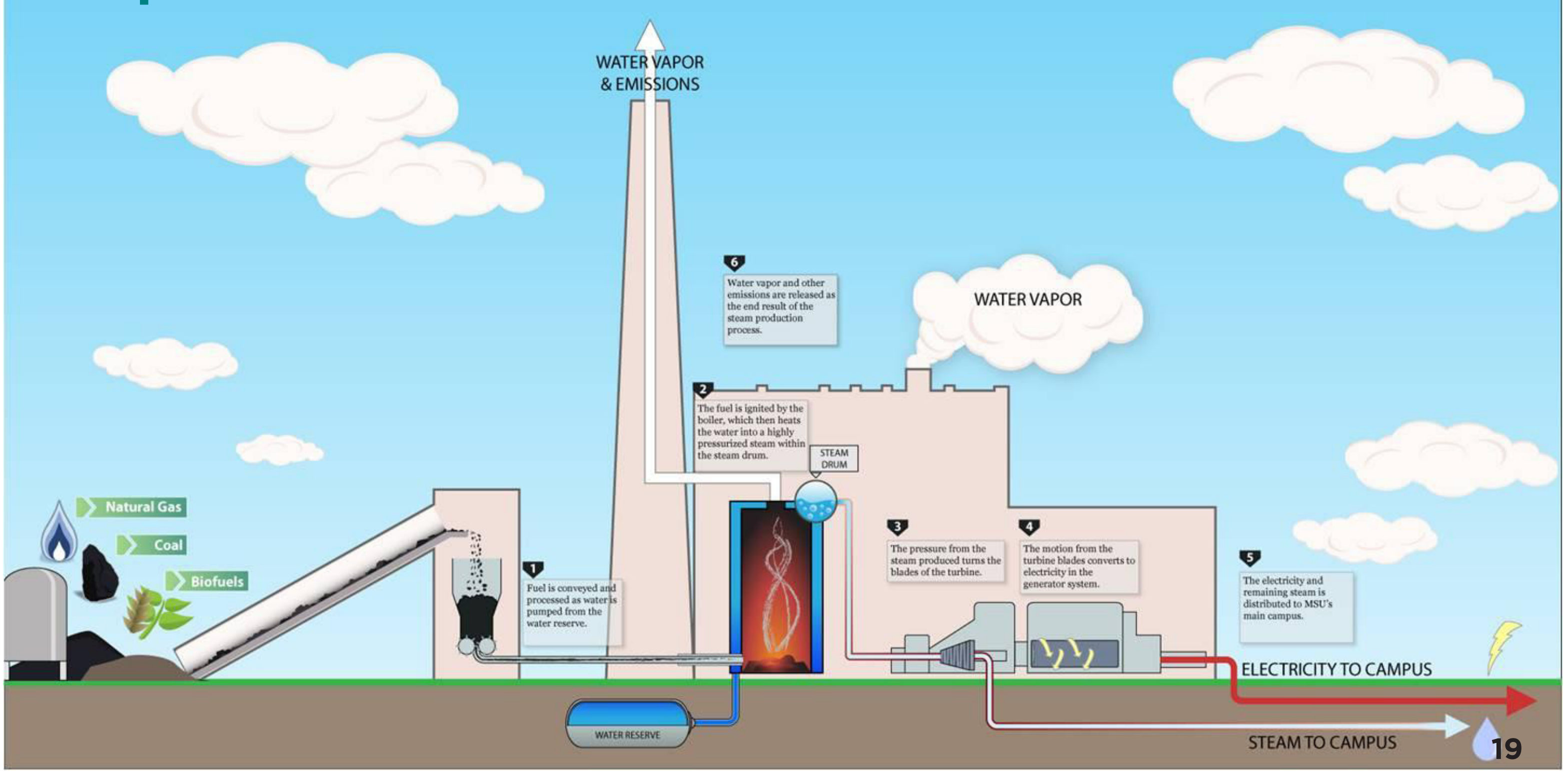
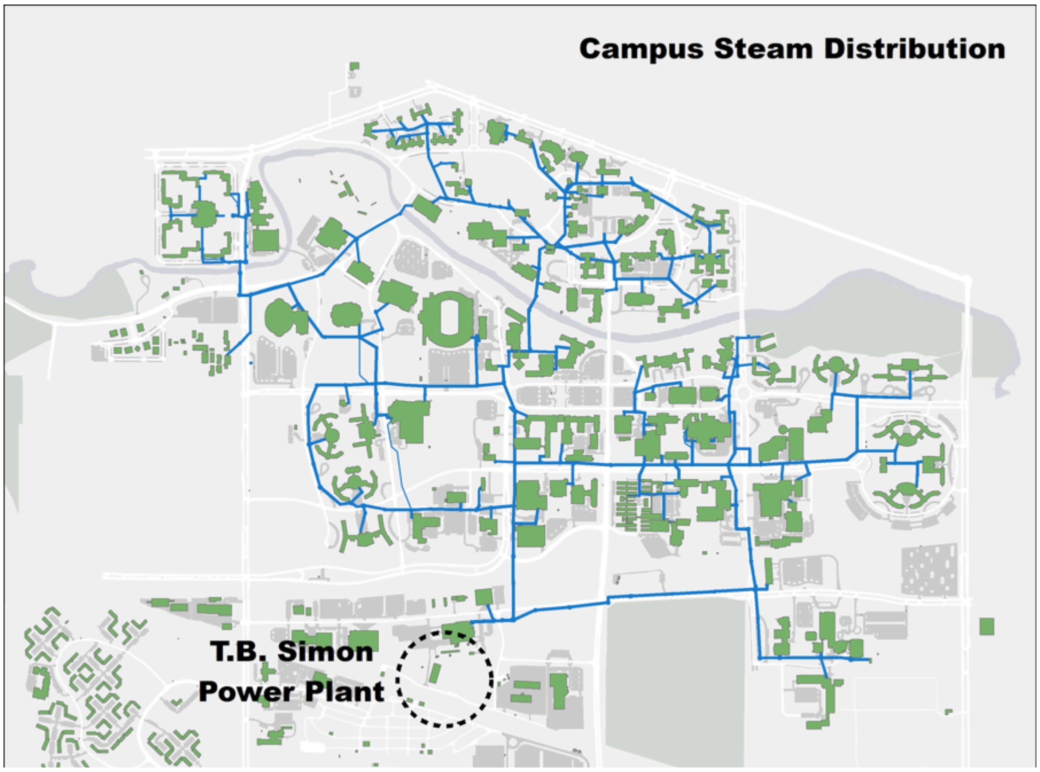


FIGURE 2 North campus steam tunnel map



REDUCING ENERGY DEMAND

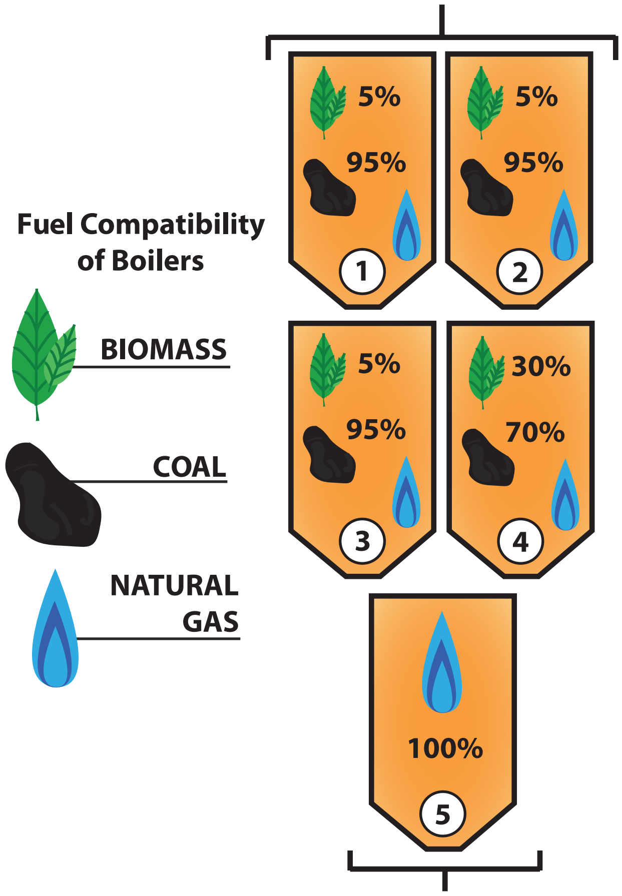
Energy conservation and efficiency tools incorporated at MSU in recent years have been plentiful and have helped to reduce energy demand and consumption on campus.

Retro-commissioning, or tuning-up, of mechanical equipment, reducing run times for heating, ventilation and air conditioning (HVAC), metering buildings, installation of sensor technologies, classroom consolidation, energy educator programs, smart meters, improved power management in computer labs, and consolidating high-energy using computer servers have all had an impact. BTUs/gross square foot has steadily decreased since FY2006-07, indicating that the campus has become more efficient in using energy due to energy conservation programs.

Despite these efforts, campus growth threatens to negate their impact. Historically, the MSU campus has added approximately 1 million square feet per decade. However, in the most recent decade, campus square footage grew by 2 million square feet and much of the new construction was in high-energy research buildings such as the Facility for Rare Isotope Beams (FRIB) and the Plant and Soil Sciences Building. These projects will contribute a 2%

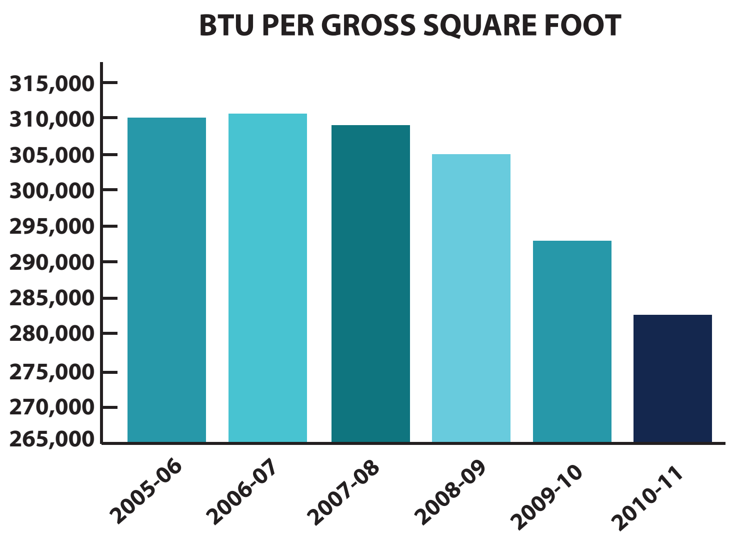
FIGURE 3 Fuel compatibility for the power plant boilers

These four boilers are now permitted to burn biofuels. Boilers 1,2, and 3 can burn 5% biofuels, boiler 4 can burn 30% biofuels. Biofuel suppliers still being determined. Each boiler can burn natural gas as well.



The fifth boiler uses only natural gas.

FIGURE 4 Energy used per square foot for the campus. Since FY 2006, energy use per square foot has decreased by about 9.5% indicating an improvement in energy efficiency.



increase in the average annual energy consumption. Unless MSU actively chooses to prevent campus growth, the only way to reduce demand is to increase energy conservation and efficiency measures.

GOVERNMENT REGULATIONS

Expected changes in federal and state regulations likely will force MSU to transition to new energy sources.

Currently we have no national energy policy guiding organizations (such policies are under debate) making it a difficult planning environment for an energy transition. The federal government does have energy requirements, but they are applicable only to federal facilities. These requirements cover energy reduction, sustainability goals, renewable fuel production, and increasing energy security. Under the Clean Air Act, MSU is subject to the Clean Air Interstate Rules (CAIR) for ozone season for nitrous oxides (NOx) and the National Ambient Air Quality Standards (NAAQS) for sulfur dioxides (SOx). Power plant boilers are subject to New Source Review (NSR) requirement which reviews any significant modifications to boilers. The new Boiler MACT rule, which would impose stricter air emissions standards would also impact the campus.

Meanwhile, many states have moved forward with energy regulations, but they vary in terms of how they are defined and performance levels. In Michigan, the Renewable Energy Standard requires electric providers to achieve a retail supply portfolio that includes at least 10% renewable energy by 2015.

These regulations along with current debates in the states and in Congress clearly indicate that more energy and air emission regulation is forthcoming. A key part of this will be an effort to reduce man-made contributions to climate change, specifically global warming, through new regulations on GHG emissions from man-made processes.

Fossil fuel electrical power generating stations such as MSU's are prime targets for regulation, and it is expected that rules for reducing GHGs will be in place no later than 2015. Current legislation being considered in Congress calls for overall reductions of 17-20% by 2020 and over 80% by 2050, through a cap-and-trade program that would begin in 2012.

KEY PLANNING CONSIDERATIONS

Creating an Energy Transition Plan is complex, requiring the consideration of several variables to craft a balanced and sustainable course of action. The steering committee's focus was to create a framework that moves MSU into 100% renewable energy while optimizing the five key variables of reliability, capacity, environment, health, and cost. Renewable energy includes generation technology such as solar, wind, biomass, hydroelectric power, geothermal systems, anaerobic digestion, and others.

RELIABILITY

Reliability refers to the ability to have power when it's needed. The level of reliable power can have significant impact on our teaching, research and outreach. Many research programs would be highly compromised with power outages. For example, the National Superconducting Cyclotron Laboratory, a world-leading rare isotope research and nuclear science education center serving more than 700 researchers from 100 institutions in 35 countries, estimates that after a significant power outage, it would need as much as one month to return to full operations. In addition, there are approximately 17,000 on-campus residents that require reliable power for housing, dining, and life safety systems.

Currently, MSU operates the power plant with redundant systems to ensure reliability. In the event of a complete plant outage, the university has the capability to independently restart the plant in a very short time period. The system's reliability and redundancy enabled the university to maintain full operation during the 2003 blackout. The power plant's interconnection to the local utility also provides reliability to the university in the form of emergency electricity supply.

As MSU incorporates more renewable technologies, the university must decide how to "firm" the renewable energy, or back up the power, so that the current level of reliability is maintained. For example, solar panels create energy only when the sun is shining. Less power is generated on cloudy days, presenting problems in a region that according to the National Climate Data Center records at least 80% cloud cover for an average of 190 days each year.

Energy storage technology, although not currently viable for MSU now, could be a solution to storing renewable energy to be available when it's needed. There are several Department of Energy sponsored storage projects underway.

CAPACITY

Capacity refers to the amount of energy that MSU can supply to the campus.

Firm capacity is the maximum amount of energy available at the power plant. There are firm capacity limits for steam and electricity. Assuming a growth rate of 2 million square feet per decade, it is expected that MSU will hit its firm capacity for steam in 2018 and electricity in 2039. If the university continues business as usual, MSU would need to find means to provide additional power to the campus. It is estimated that an addition to the power plant similar to the Unit 4 capacity that was added in 1993, could cost as much as $100 million.

Building energy use also is a large factor in capacity. Lately, new buildings and renovations have higher energy intensity due to the research functions carried out in the space as well as the fact that newer buildings in general have higher cooling, ventilation, and air conditioning loads. Additional construction of high-energy consuming units could further stress capacity.

FIGURE 1 MSU Greenhouse Gas Emissions from 2000-2010 as reported to Chicago Climate Exchange

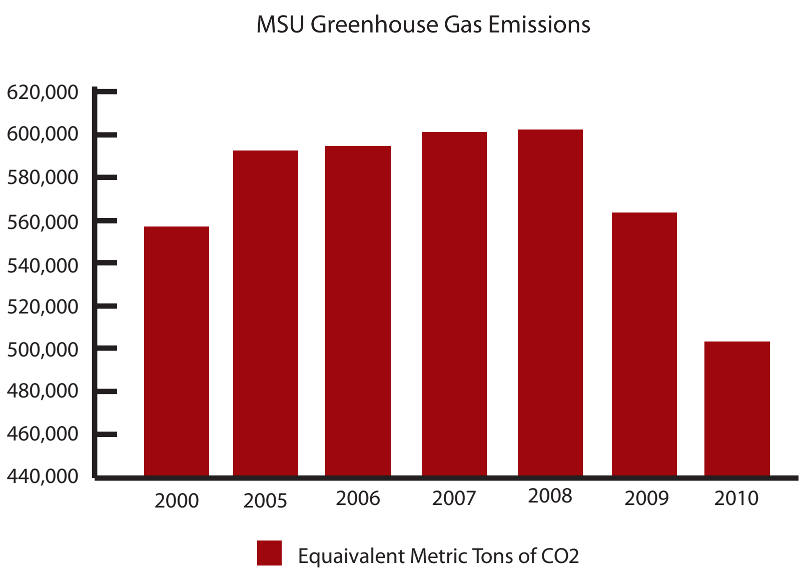


FIGURE 2 Greenhouse gases in the Earth's atmosphere as seen from space

ENVIRONMENT

Several factors can be used to describe the environmental impacts of the energy infrastructure at MSU. In this case, the environmental impact is defined by greenhouse gas emissions (GHGs). This includes six gasses: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. GHGs are measured in terms of carbon dioxide equivalents or (CO2e). Greenhouse gases from the burning of fossil fuels are thought to be the largest contributor to climate change. Reducing the use of fuels such as coal and natural gas and using renewable energy will drastically decrease GHGs.

MSU completed a GHG inventory as a part of its membership to the former Chicago Climate Exchange (CCX), and continues to track its performance each year. This inventory includes direct emissions from the power plant and MSU-owned vehicle fleet. Since joining the CCX, MSU reduced its GHG emissions by 6% below a 2000 baseline and 9% below a 2009 baseline.

HEALTH

It is important to recognize that there are both benefits and adverse effects of any energy system. Providing reliable power to the community is beneficial. The adverse health effects considered in this plan were the result of air pollution, specifically particulate matter, NOx and SOx. Depending on the fuel burned, different levels of these pollutants are emitted in the combustion process.

Combusting fossil fuel produces air emissions that have been linked to respiratory problems such as asthma, lung cancer, heart disease and other health problems. Additionally, coal ash – the waste left after coal is combusted – presents significant health and environmental risks if toxins leach into the ground and water supply.

Emission control technology has been installed at the power plant to reduce NOx, SOx, particulate matter and coal ash. To reduce nitrous oxides, staged combustion has been installed to avoid the higher flame temperatures that produce NOx from the nitrogen in the air, and urea is mixed to reduce NOx from fuel based nitrogen. To mitigate sulfur oxide emissions, limestone is added in a process called flue gas desulfurization to reduce sulfur oxide emissions by 95%. In addition, bag houses are used to collect approximately 99% of particulate matter (much like a vacuum cleaner filter). MSU dry coal ash management practices, with the local regulated public solid waste landfill, exceed what are expected to be the requirements for developing coal ash regulations.

COST

To be certain, affordability is a key element of any viable Energy Transition Plan. MSU has limited capacity to increase tuition or borrow money to pay for improvements recommended in this plan.

This plan considers the full cost of ownership, including capital investments, operational costs, disposal costs, end-of-life cost, manufacturing cost, transportation costs and costs of financing investment (debt service). The committee also considered how these costs affected tuition and the university's credit rating.

A financial model was created by external consultants to help the committee determine the impact of various scenarios on the costs identified above. Social and external costs were discussed, but the committee did not quantify them in this plan.

When discussing costs, revenue also was considered. The university's main sources of revenue are tuition, state appropriations, debt financing, development funding, and grants. The financial model assumed that funding for strategies came from tuition and debt financing, but it is important to recognize that other revenue resources should be incorporated as available.

Auxiliary units such as Residential and Hospitality Services and Athletics do not receive general fund monies and are billed directly for energy. As such, for these units, a significant rise in energy costs impacts their operations.

PLANNING ASSUMPTIONS

The steering committee developed a set of planning assumptions to guide its work:

- The MSU campus will consider both a central steam source for heating and cooling and distributed power generation. Future investment decisions (whether for replacement of current centralized steam generation capacity or installation of new distributed sources) will be evaluated on a case-by-case basis.
- Demand for additional campus facilities and renovations of existing facilities will continue.
- Policies, regulations and other constraints on energy production will be more restrictive in the future; a reduction of GHG emissions and other emissions will be necessary to meet future regulations.
- Energy costs will continue to rise significantly faster than the historic general rate of inflation.

- Portions of campus require that power be available 100% of the time for critical needs. Today, reliability for the power plant is defined as having a firm capacity of N-1, which is being able to meet the campus peak energy demand with the largest generating unit out of service.
- The Energy Transition Plan covers the contiguous East Lansing campus, including properties served by the T.B. Simon Power Plant and other contiguous properties served by local utilities. A separate plan may be required for other properties outside of the contiguous campus.
- The plan includes the impacts of MSU's motor pool fleet, but not the impact of private vehicles on campus. A separate plan may be required to address energy and emissions from private vehicles.
- Building infrastructure will continue to be managed with energy efficiency as a priority.
- Education of the campus community will continue regarding the need to conserve energy.
- Necessary incentives to encourage energy conservation by individual campus customers (behavior modification), and connections between actual energy use and cost will be established.
- FRIB will not be powered by the T.B. Simon Power Plant

INTEGRATED PLANNING MODEL

To best guide the plan, MSU contracted with an independent and highly regarded energy consulting firm to develop an integrated planning model specific to the university that could reasonably show the impacts of energy decisions.

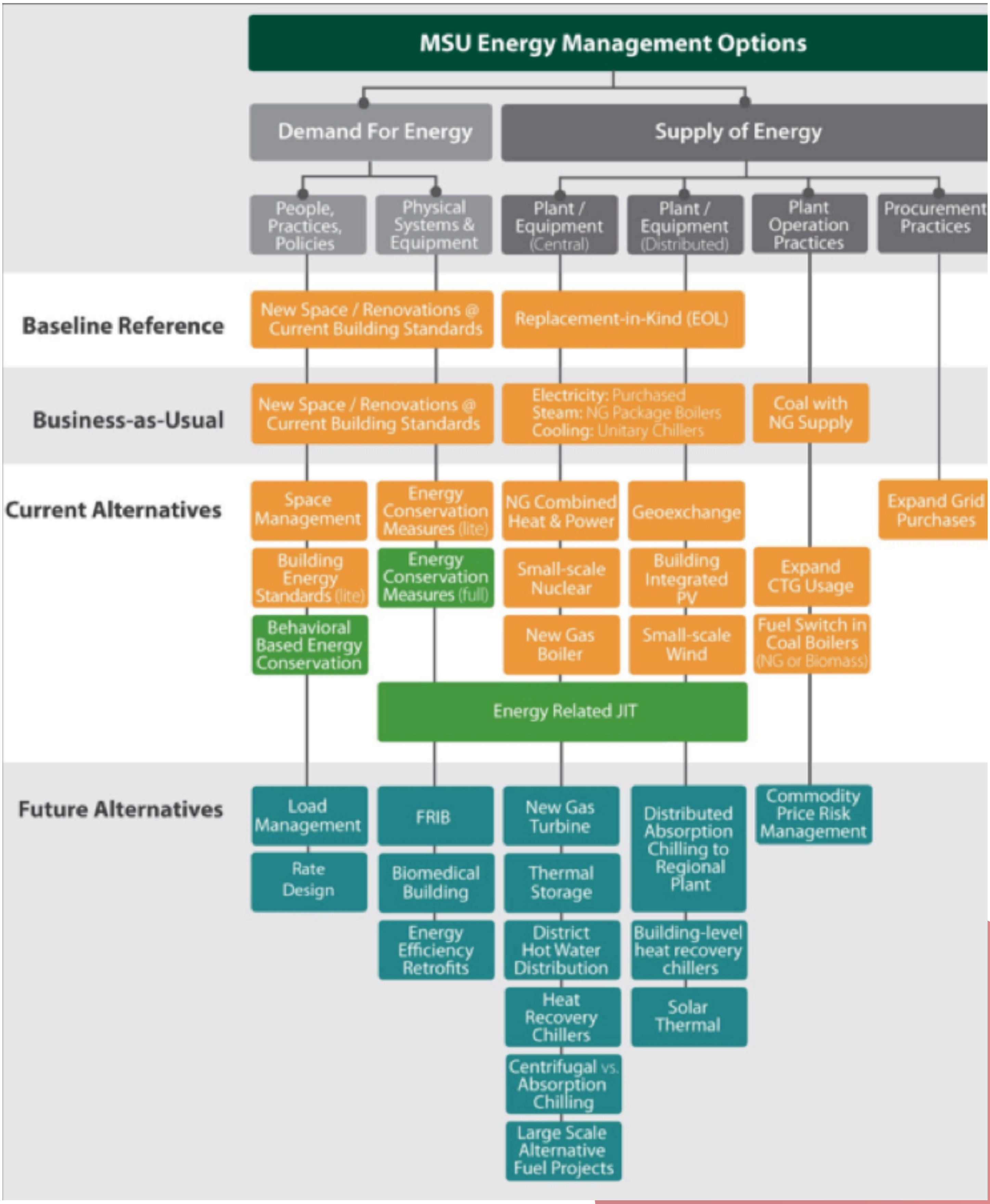
The relationships between variables in the model are interrelated and complex. The model takes what we know about MSU's energy system to forecast decision outcomes. The model allowed the committee to set realistic targets and understand the outcomes and trade-offs of particular strategies. It also ensured that the plan would be built on solid research rather than beliefs and opinions of committee members.

The model compares different scenarios against a business-as-usual (BAU) case. The business-as-usual case assumes that the campus continues to grow at 2 million square feet per decade, requiring a $24 million capital investment in 2015 to comply with the U.S. Environmental Protection Agency's 2010 Boiler MACT rule expected to impose stricter emissions limits and other requirements. It also assumes that as boilers in the power plant reach the end of their useful life, they will be replaced with natural gas turbines. The BAU case also provides estimates for energy savings due to energy conservation and efficiency programs.

The committee used the Integrated Energy Planning Model to explore supply and demand side strategies and develop an understanding of the trade-offs to achieve the most optimal outcomes. The goals above were chosen because the combination of strategies optimized campus renewable energy and minimized GHG emissions. At the same time, these goals delayed the need for additional plant capacity, maintained energy reliability for the campus, stayed below a tuition threshold, and minimized negative impacts on the environment and public health.

Although the model goes through 2050, the committee believed that trying to predict reasonable energy options and performance beyond 2030 would be difficult due to campus growth, rapidly emerging technologies and anticipated regulatory changes. During each major five-year review, there would be opportunities to review performance and options beyond 2030 as information becomes available and the model is revised based on changes in operations.

FIGURE 3 Integrated Energy Planning Model



VISION & GOALS

The Michigan State University Energy Transition Steering Committee recommends that MSU adopt a vision of moving toward 100% renewable energy. To achieve this vision, energy supply and demand must be addressed, new knowledge created, and partnerships strengthened. The following plan outlines the steps needed to move toward the vision while balancing capacity, health, reliability, environment, and cost. The key interrelated goals are to:

1. Improve the physical environment.
2. Invest in sustainable energy research and development.
3. Become an educational leader in sustainable energy.

The committee was asked to develop a set of goals and recommend broad strategies to move MSU toward a long term vision. Similar to the Campus Master Plan, the Energy Transition plan does not recommend, specific operational decisions, but provides a general framework for the university to make operational decisions. This allows the campus to be flexible in its decisions while moving toward the overall vision.

In developing this Energy Transition Plan, the steering committee considered all strategies available and used the Energy Strategies Model to plug in strategies for developing goals that are both achievable and aggressive, and will move MSU toward its vision.

The five-year review process for the Energy Transition Plan will include a validation or revision of the goals so that MSU makes continuous progress toward the long-term vision. If MSU can set more aggressive goals, it should do so.

GOAL 1

IMPROVE THE PHYSICAL ENVIRONMENT

The committee recognizes that MSU cannot move to 100% renewable energy overnight. At this time, MSU cannot feasibly and reliably buy and/or generate 100% renewable energy from current sources. For example, solar energy technology has been used on campus, but according to the Black and Veatch report on next generation energy technologies, covering all of MSU's roofs with solar panels would only generate 11-13% of the electricity needed. The anaerobic digester being proposed will account for 0.5 MW of the 61.4 MW of campus electrical demand.

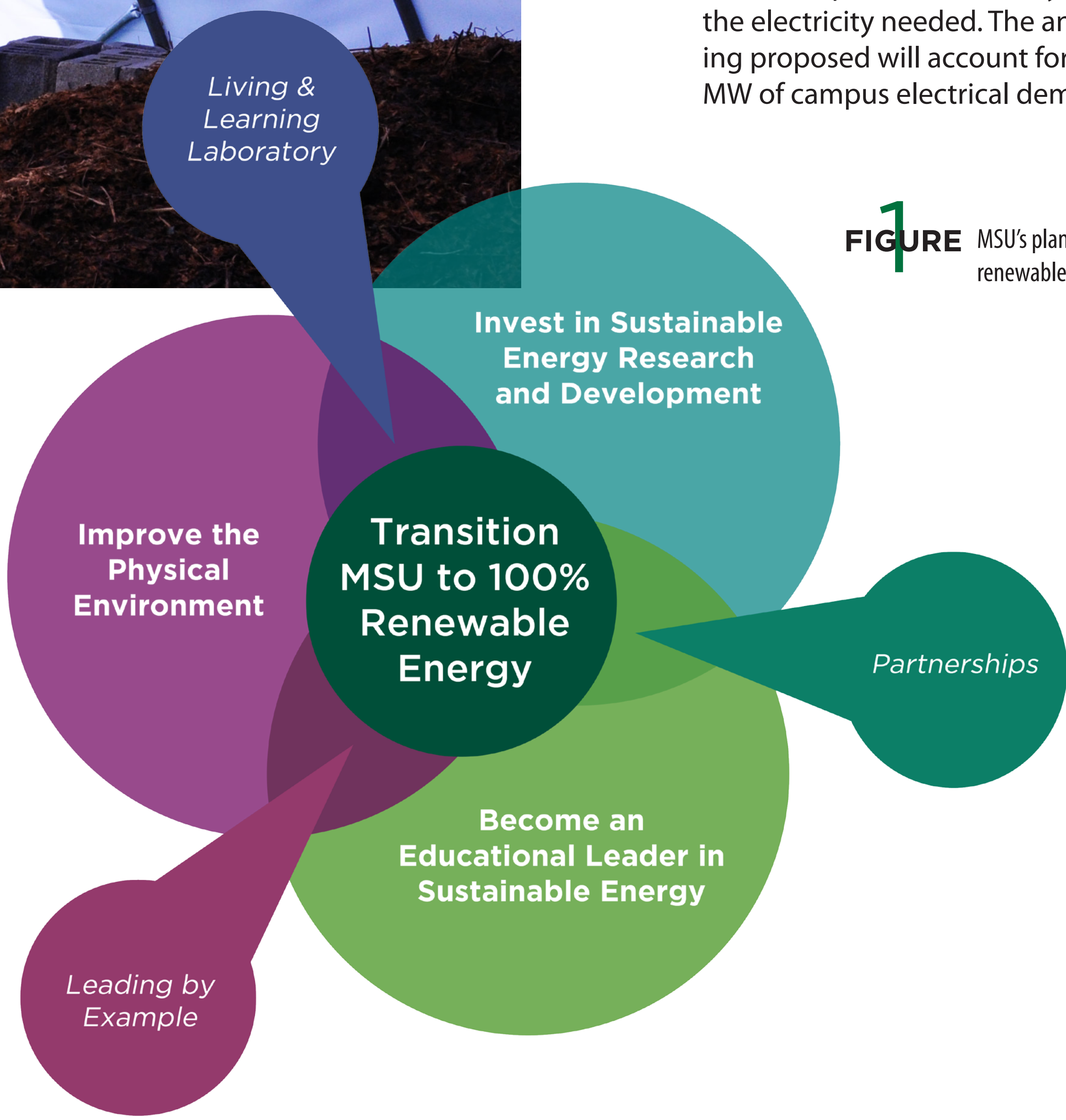


FIGURE 1 MSU's plan to transition to 100% renewable energy

FIGURE 2 Powering the future: Incorporating renewable energy while reducing emissions

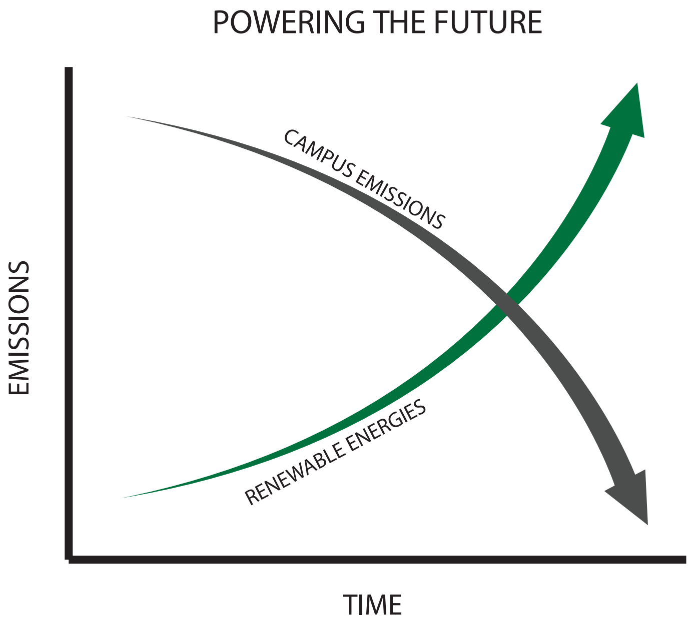


FIGURE 3 Recommended campus renewable energy and greenhouse gas emission targets through FY 2030

	% Campus Renewable Energy	% Greenhouse Gas Emission Reduction
FY 2015	15	30
FY 2020	20	45
FY 2025	25	55
FY 2030	40	65

Until MSU can build or purchase its steam and electrical needs from renewable resources, certain "bridge" technologies must be used.
When selecting both supply and demand side technologies while moving toward clean energy, MSU should select technologies that also decrease campus emissions, thus reducing negative impacts on to the environment and on human health.

The committee believes that the targets outlined in this goal can be achieved with the knowledge available today. It is conceivable that as technology changes, the university could accelerate its progress. What we know today and what we may know in five years could be drastically different in terms of available research and technology as well as state and federal regulations.

The targets for renewable energy increases and GHG reductions are set in five-year increments beginning in fiscal year (FY) 2015. The goals reflect progress compared to a FY 2010 baseline. The target for renewable energy is larger in FY 2030 (15% versus 5% in previous years) because there is potential opportunity at the end of power plant equipment life to switch out to more renewable energies.

These targets are set based on consideration of projected campus growth and energy needs, and a number of alternatives in terms of available and emerging technologies, cost effectiveness, reliability and implications for MSU's cost structure. The targets maintain a reliable energy system, meet capacity and push out the need for additional capacity beyond 2050, and reduce emissions that negatively impact health and the environment.

The committee evaluated several scenarios to develop the targets. Figure 4 shows three examples of different scenarios evaluated with the Integrated Energy Planning Model. Key input areas such as space management, energy conservation & efficiency, fuel switching, and renewable energy options are shown. Required capital, cost of utility services (CUS), GHG reduction and capacity are performance indicators.

The committee discovered that while different strategy combinations can get the university to its targets and move toward the vision of 100% renewable energy, there is no perfect scenario – each has a set of trade-offs. Thus, the committee is recommending a combination of strategies that

Inputs

	Space Management	Energy Conservation & Efficiency (retro-commissioning, conservation measures)	Fuel Switching	Renewable Energy (biomass, green energy, renewable generation)
Base Case (BAU)	2 million square feet per decade growth			
A	1.5 million square feet per decade growth	$10 million invested in 2012, 2015, 2018	100% NG in boiler 3, 10% in boilers 1, 2	30% biomass in boiler 4, 10MW off peak green power purchased
B	1.5 million square feet per decade growth	$10 million invested in 2012, 2015, 2018	Max NG switch, 100% in boilers 1, 2, 3, 46% in boiler 4	
C	1.5 million square feet per decade growth	$10 million invested in 2012, 2015, 2018		All new construction is powered with geothermal energy building integrated solar panels

Performance Indicators

	Required Capital (In millions)	CUS in 2030 (In millions)	GHG Reduction by 2030	Capacity Tipping Point
Base Case (BAU)	$108.1	$86	2%	Steam 2018 Electricity 2039
A	$94.8	$65.7	53%	Beyond 2050 for steam and electricity
B	$94.8	$72.9	36%	Beyond 2050 for steam and electricity
C	$177	$62.8	40%	Beyond 2050 for steam, 2048 for electricity

FIGURE 4 Examples of potential energy transition strategies and scenarios. Multiple scenarios were run in the model to determine the GHG and renewable energy targets that were aggressive and achievable.

balance the five key variables (reliability, capacity, environment, health, and cost) while reaching the goal of 100% renewable energy in the most prudent and efficient way.

Additionally, the committee believed that conservation had to be prioritized. The most efficient energy was the one that did not need to be produced. Beyond that, there were several supply side strategies that could be explored.

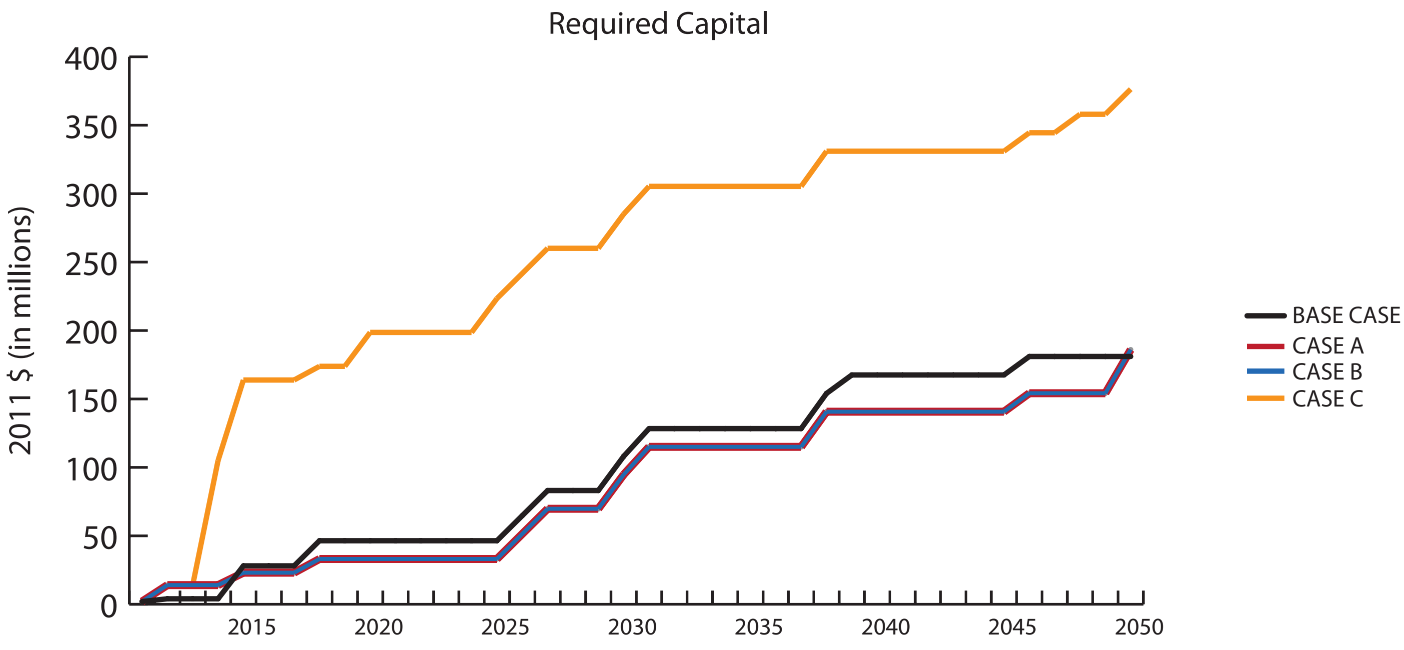


FIGURE 5 The black line indicates the business as usual case. Scenario A and B require the same capital and thus the lines are on top of each other.

Scenarios A, B, and C are shown in comparison to the base case to show the impacts and trade-offs of key variables. The targets were set after examining these trade-offs and considering what the university could reasonably achieve while balancing cost, capacity, reliability, health and environment.

REQUIRED CAPITAL

The required capital becomes an important consideration for the financial health of the university. MSU's long term Moody's credit rating is Aa1. If the university uses significant debt to finance capital projects, it can lower its credit rating and increase the cost of borrowing money. It can also impact its ability to use debt to finance other, non-energy related projects.

In this example, scenario C is the most aggressive in incorporating renewable energy to MSU's energy infrastructure; however the required capital is high and exceeds the debt capacity of MSU's Aa1 rating. Scenario A adds less renewable energy to the campus, but stays under the debt capacity limit.

COST OF UTILITY SERVICES (CUS)

Cost of Utility Services refers to the set of expenses required to provide energy to the campus. They include operating costs and debt service from capital investments. Because the committee

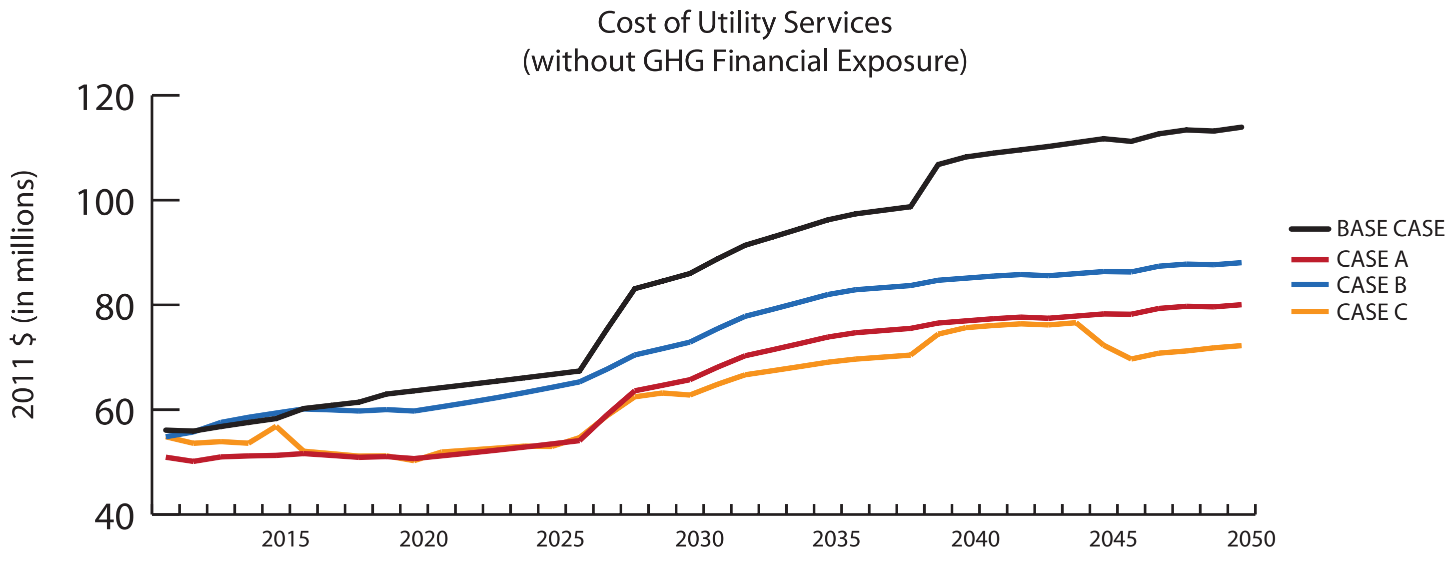


FIGURE 6 Cost of Utility services includes capital costs, operation and maintenance costs (which includes disposal costs), delivered fuel expenses, and avoided costs.

is not recommending precise, everyday operational decisions, the cost of utility services can range.

From the examples in scenario A, B and C it is clear that conservation paired with supply side strategies reduces the cost of utility services from the business-as-usual scenario.

Based on the model, an investment of $30 million to $40 million in energy conservation measures over the next 10 years as well as increased investments per square foot of new construction to meet more stringent energy related building standards will be required in order to meet the targets. By the time they are fully implemented, these investments should yield approximately a 15% to 25% reduction in the average annual costs of utilities relative to the business-as-usual case. This funding then should be re-invested into other energy-related activities such as implementing additional conservation measures, funding the increase in fuel costs from fuel switching, and adding renewable energy to campus.

RELIABILITY

The power plant currently has a reliability standard such that it can continue to operate when the largest unit is out of service. The scenarios outlined above maintain the same level of reliability.

As more renewable energy is incorporated, there must be solutions to maintaining an ad-

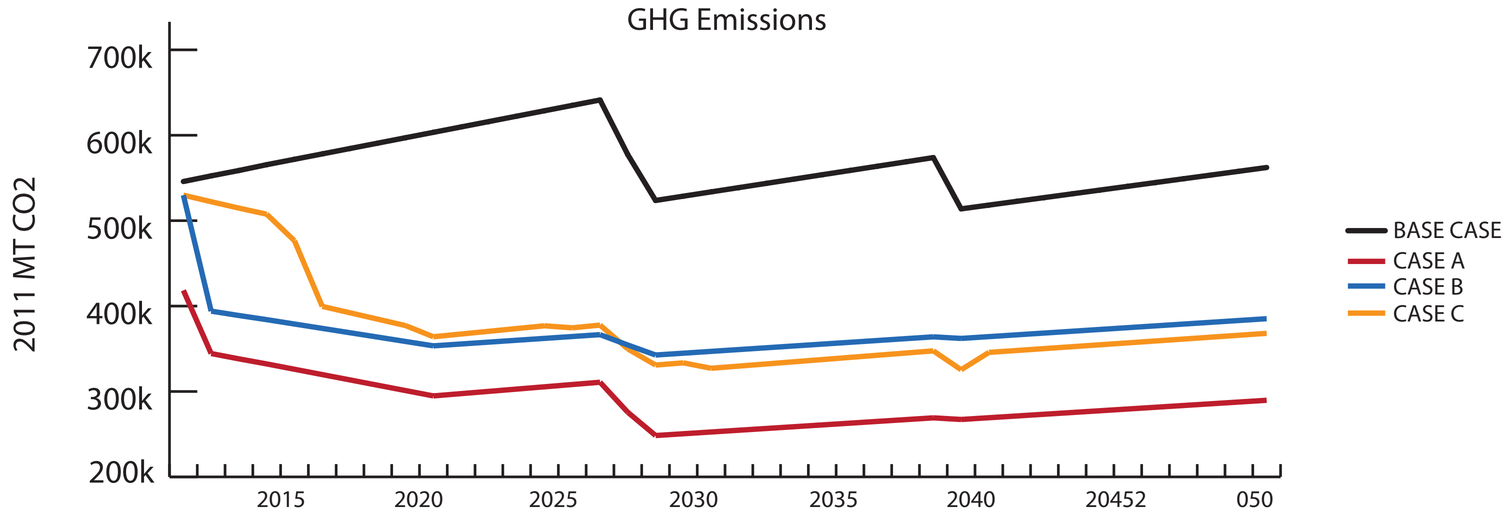


FIGURE 7

This graph shows GHG emissions in terms of metric tons of carbon dioxide equivalents (MTCO2e). The black line represents the BAU case. The sharp decline in the reference case represents the assumption that when boilers reach the end of their useful life, they are replaced with natural gas turbines. Scenario C and the reference case reduce greenhouse gas emissions over time, but scenarios A and B reduce emissions sharply through 2015 and sustain lower greenhouse gas emissions through the planning horizon. By 2030, scenario A reduces greenhouse gas emissions by 53%, a greater reduction than the other scenarios.

equate level of reliability for critical university functions. Some renewable technologies, such as wind energy and solar power, are dependent on factors that are not completely predictable. As such, development of energy storage technologies will be critical in incorporating these types of renewables into the campus portfolio as primary power sources. Otherwise renewable resources need to be backed up by grid power purchases. However, other options such as anaerobic digestion, converting waste and food to biogas, could be expanded to provide reliable, renewable energy.

GHG REDUCTION

The largest contributor to GHGs and other air emissions is the combustion of fossil fuels. Therefore, greenhouse gas emissions and other air emissions that impact health (NOx, SOx, and particulate matter) are closely correlated. GHG emissions data was used as a measure of environmental impact and public health impact.

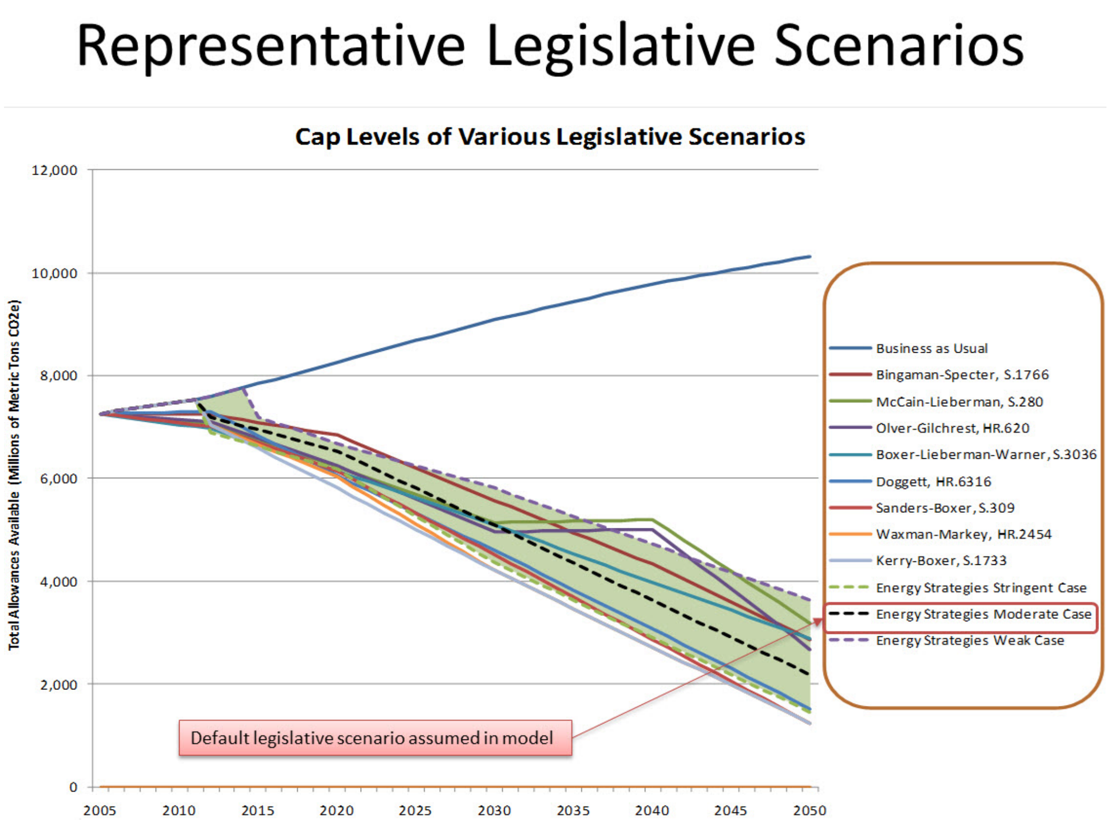
These scenarios show that it is possible to achieve significant GHG reductions as early as 2015. The most significant reduction occurs when a combination of supply side strategies is combined with conservation strategies. Reducing GHGs reduce the negative environmental and health impacts of the energy system.

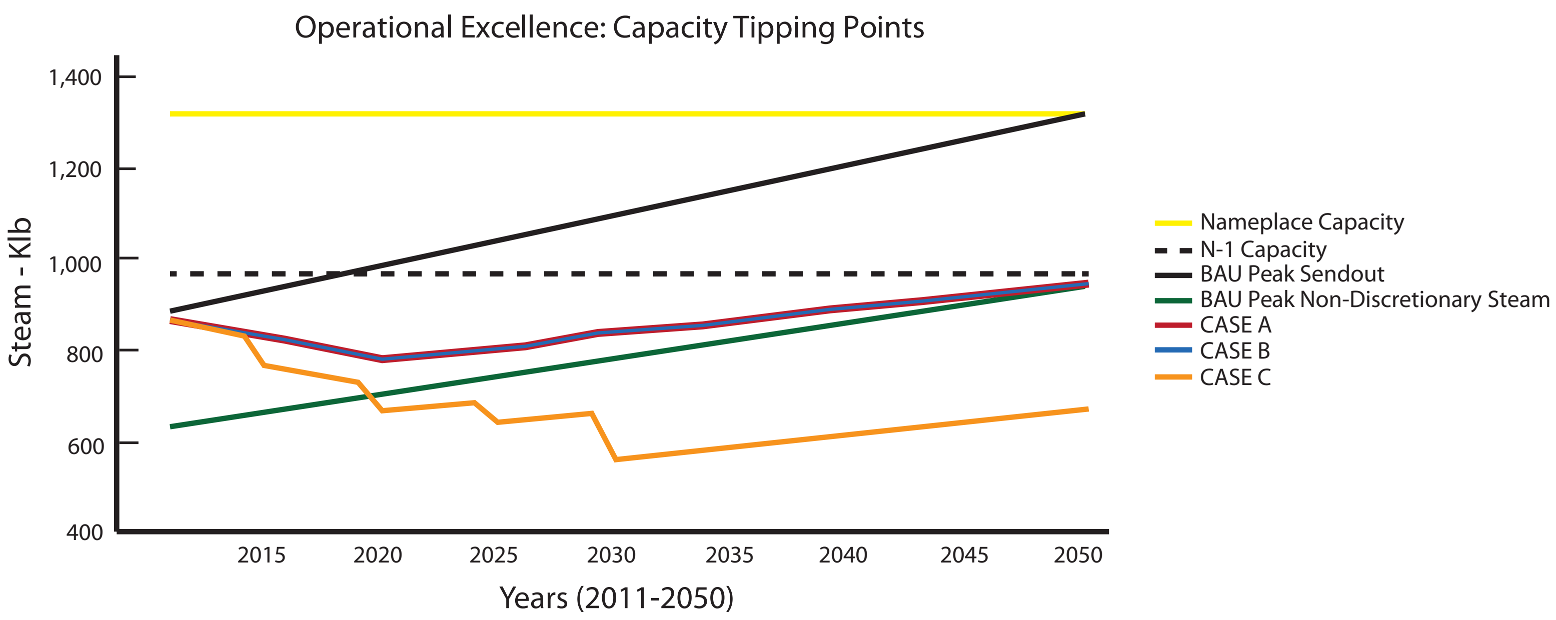
In addition, action now positions MSU to avoid significant costs and risks expected under possible future regulatory and legislative scenarios designed to place a price on greenhouse gas emissions or the use of fossil fuels for the production of energy. Projecting out through 2050, the Integrated Energy Planning Model shows MSU could potentially save an estimated $200 million to $250 million in potential costs levied on greenhouse gas emissions due to reduced financial exposure. Inaction now, could lead to a high financial risk to the institution later. Proactively developing an Energy Transition Plan that moves to renewable energy and significantly reduces GHG emissions will mitigate financial risk for the university.

CAPACITY

Assuming a growth rate of 2 million square feet per decade, it is expected that MSU will hit its firm capacity for steam in 2018 and electricity in 2039. If the university continues business as usual, MSU would need to find means to provide additional power to the campus. This type of expansion could be $100 million or more based on figures from the last power plant expansion.

FIGURE 8 The potential impact on proposed regulatory and legislative scenarios on GHG emissions. Bills in Congress have been proposed to limit the amount of allowable GHGs. Emissions beyond the cap could be subject a tax or fine. The dark blue line shows the amount of GHGs emitted in MSU's business-as-usual case. The other lines show the amount of GHGs allowed under proposed legislation.





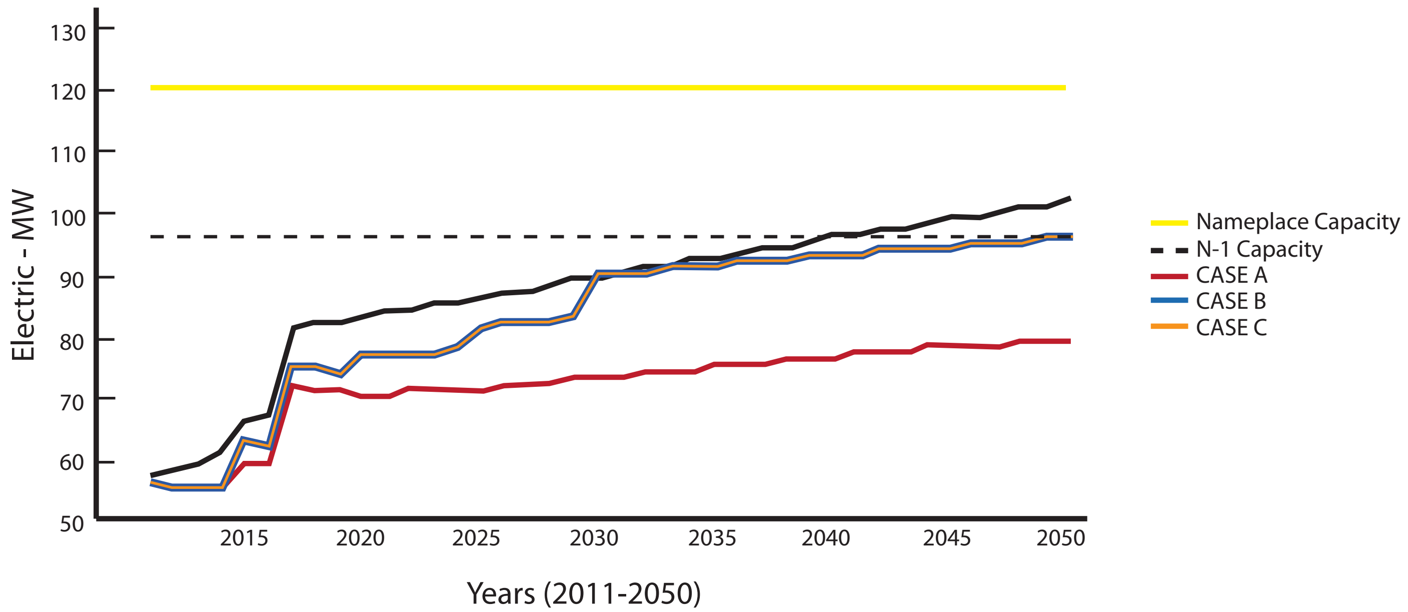


FIGURE 9 In the steam and electrical capacity graphs, the dotted line represents the firm capacity, or the point in which additional steam or electricity will be needed. Scenario A (red) and B (blue) perform similarly, thus the lines overlap in the graphs

The strategies in scenarios A, B, and C would push the firm capacity tipping points for steam beyond 2050, thus delaying the need for an expensive plant expansion using current technologies. This does not necessarily mean that the university should wait until 2050 to invest in power generation technologies, but it does allow the university the opportunity to invest in energy conservation and allow more time to consider emerging power generation technologies.

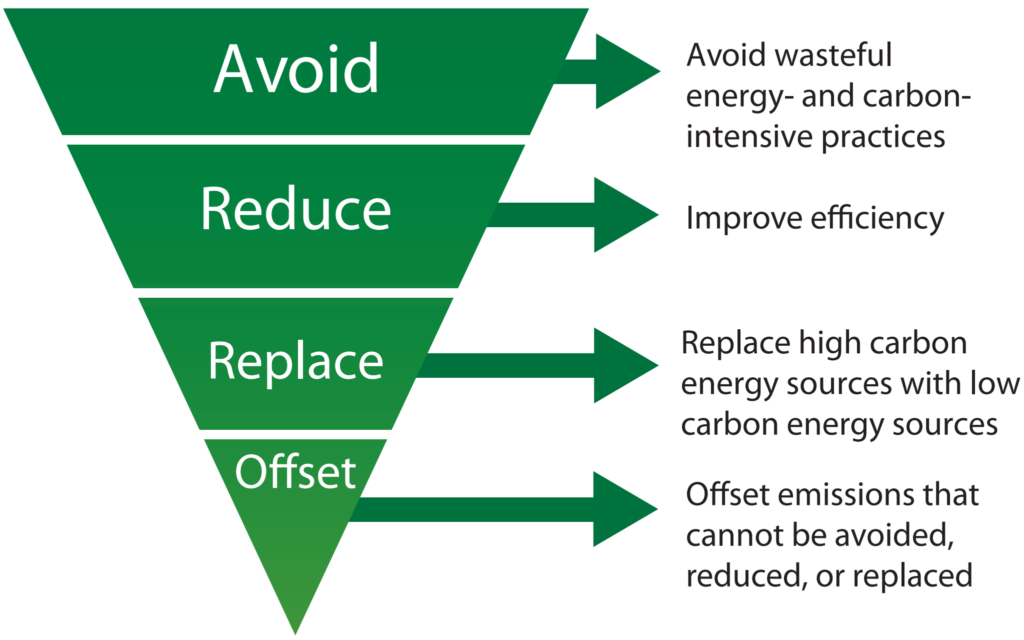
After analyzing several scenarios, it was clear that there is no magic bullet. Each decision had a set of trade offs. However the optimal scenarios used combinations of strategies to reduce greenhouse gas emissions, add renewable energy infrastructure in a cost effective manner. As a result, the committee recommends that the university pursue a combination of strategies prioritized by the hierarchy below.

Prioritizing strategies this way maximizes GHG emissions reductions and costs savings while allowing the university to add renewable energy infrastructure.

Recommended Strategies:

- **Pursue aggressive, sustainable energy conservation and re-invest energy savings for future energy needs**
- **Implement a smart growth strategy to minimize the amount of new square footage added to the campus**
- **Create a system that connects energy and space costs and incentives to end users**
- **Implement more aggressive building energy standards**
- **Continue to review and improve energy efficiency**
- **Maximize switching to alternative, cleaner fuels (subject to availability, technical, and regulatory constraints)**
- **Implement smart-grid technology**
- **Purchase green power**
- **Create large-scale renewable projects**
- **Utilize carbon offsets**
- **Educate the community on MSU's energy system and continue behavior change for energy conservation**

FIGURE 10 Strategic prioritization of energy transition strategies



AVOID WASTEFUL ENERGY- AND CARBON- INTENSIVE PRACTICES

Pursue aggressive, sustainable energy conservation and re-invest energy savings for future energy needs

The most efficient unit of energy is the one the campus does not have to produce. Conservation projects such as commissioning/retro-commissioning of buildings, changing laboratory controls to reduce HVAC consumption, and improving classroom and event scheduling should result in reduced energy consumption. Although these efforts are currently happening on campus, they should be accelerated in order to meet the targets recommended by the committee. As energy savings are realized, the funds saved from the fuel budget should be reinvested for future energy needs such as fuel switching and renewable energy infrastructure.

Conservation also will give the university more time to think about the right technology for addressing future capacity needs. If the university continues to grow at 2 million square feet per decade, it is predicted that the T.B. Simon Power Plant will reach its firm capacity for steam in 2018 and for electricity in 2039 requiring an investment of $100 million or more for power plant expansion. It would be prudent to delay a decision on expanding the power plant until generation technologies are more mature.

The Integrated Energy Planning model shows that implementing the strategies in the plan will push the firm capacity dates for steam and electricity out, thus allowing more time for MSU to review and implement renewable energy sources and delay costly investment into old technologies.

Implement a smart growth strategy to minimize the amount of new square footage added to the campus

Historically, the MSU campus has grown by approximately 1 million square feet per decade. However, in the most recent decade, campus square footage has grown by 2 million square feet and much of the new construction has been of high-energy research buildings such as the FRIB, and additions to Plant and Soil Sciences Building, Life Sciences, and Wells Hall. Although much has been done to conserve energy and improve energy ef-

FIGURE 11 East Lansing campus growth from 1970 to present.

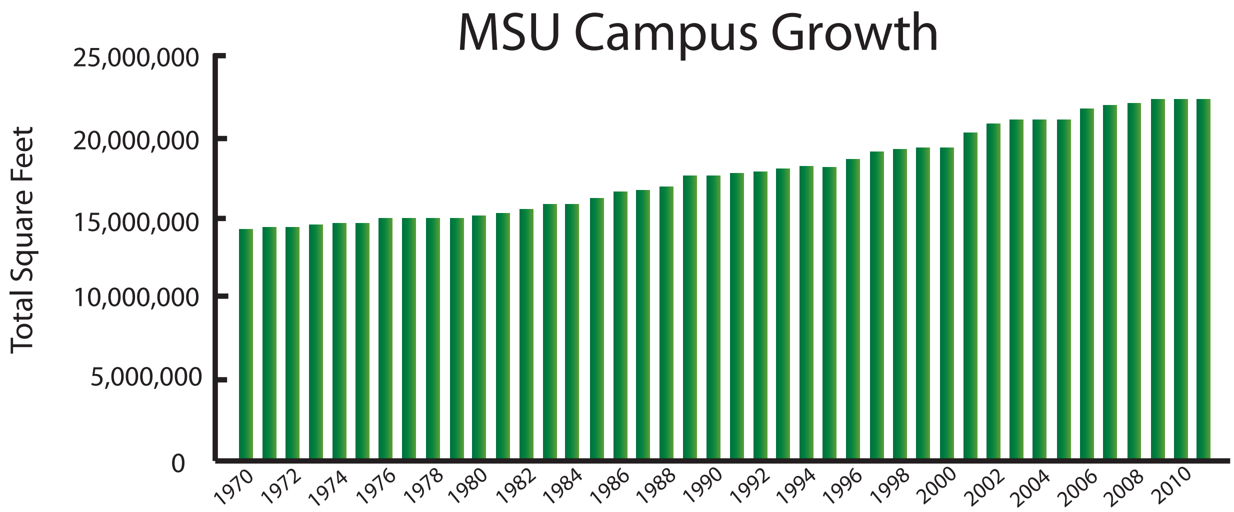
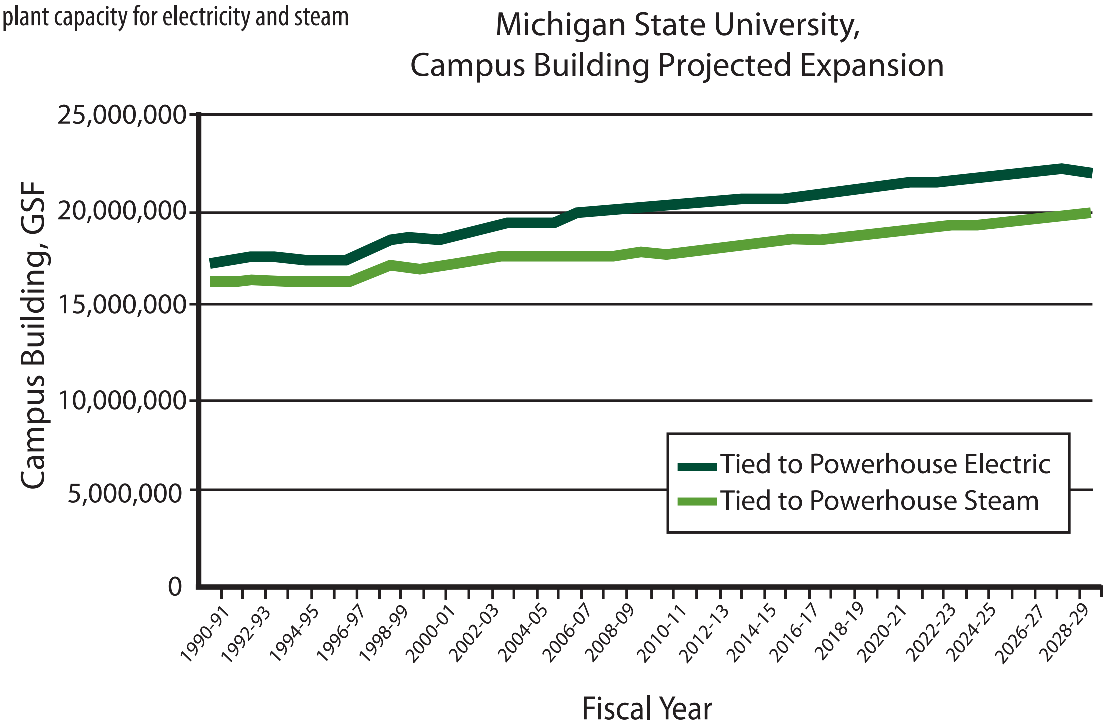


FIGURE 12 Impact of projected building expansion on power plant capacity for electricity and steam



ficiency, these gains are compromised by the new space added to campus.

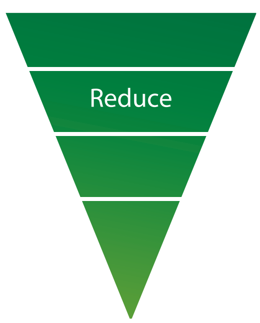
The committee believes the university should continue to pursue opportunities to address space needs by considering mixed-use spaces, flexible spaces, and strategic renovations and demolitions to slow the growth of new square footage on campus. For example, the recent Morrill Hall replacement project combined new construction, reuse, renovation and demolition to meet program needs, thereby minimizing the environmental footprint.

Slowing campus growth from 2 million square feet per decade to 1.5 million square feet per decade pushes out the firm capacity date, saves energy costs, and when in concert with conservation activities, further reduces GHG emissions. More dramatic savings and reductions can be achieved if growth slows to 1 million square feet per decade, the university's growth average prior to the most recent decade.

Create a system for distributing utility and space costs and incentives to the end user

With the exception of some auxiliary units such as Residential & Hospitality Services and Athletics, end users are not directly responsible for energy and space costs. Consequently, there is little incentive to conserve energy and/or space. Previous studies from the Environmental Stewardship Behavior Team confirm that many users do not directly associate their use to costs and are not motivated to practice conservation (switching to lower energy consuming equipment, setting up energy controls, etc.) because there was no incentive or reason to do so. Therefore, the committee recommends putting in place a system that connects the end user directly to energy and space costs. This can be accomplished multiple ways – direct billing, an incentive program, or other means. The system should account for the diversity among departments and units taking into account a program's size, ability to generate funds, etc.

REDUCE: IMPROVE EFFICIENCY



Implement more aggressive building energy standards

The Physical Plant has revised the MSU standards of construction to ensure that at a minimum, all new campus buildings would be Leadership in Energy and Environmental Design (LEED) certified if one pursued certification on the project. Some projects have gone through the complete LEED process – the Chemistry Building addition earned LEED Silver, while both the MSU Surplus Store and

FIGURE 13 Solar panels on top of the MSU Surplus Store

FIGURE 14 Bott Building being built on MSU's campus. The entire building will be heated by geothermal energy.

Recycling Center and the Secchia Center achieved LEED Gold.

The committee recommends that the university go beyond LEED certified levels and pursue more aggressive energy standards for buildings. Requiring buildings to pursue LEED Silver or higher certifications and prioritizing the energy points is one option; however, there are other standards that also can be used. For example, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has energy standards for high performing buildings.

More aggressive building energy standards could encourage the pursuit of more innovative solutions such as net-zero energy buildings and advanced energy efficiency technologies. MSU also could create a plan for retrofitting existing buildings with renewable energy sources.

Continue to review and improve energy efficiency

The committee agreed that efficiency improvement should be regarded as an ongoing area of emphasis. MSU should be prepared to pursue new efficiency strategies and technologies as they emerge. Benchmarks and trend lines can be developed to identify opportunities and monitor progress toward meeting efficiency goals in relation to the overall energy plan.

Recently, MSU joined the Better Buildings Challenge and committed to improving energy efficiency 20% by 2020 in 20 million square feet of its East Lansing campus. The effort, led by former President Bill Clinton, was launched by President Barack Obama in February 2011 to promote the construction and retro-commissioning of more energy efficient buildings in the United States.

Implement smart-grid technology

Smart-grid is a computer-based electrical grid which uses two-way digital communication and automation to predict and intelligently respond to the behavior and actions of all electric power users connected to it in order to efficiently deliver reliable, economic, and sustainable electricity services. Benefits of smart-grid technology include:

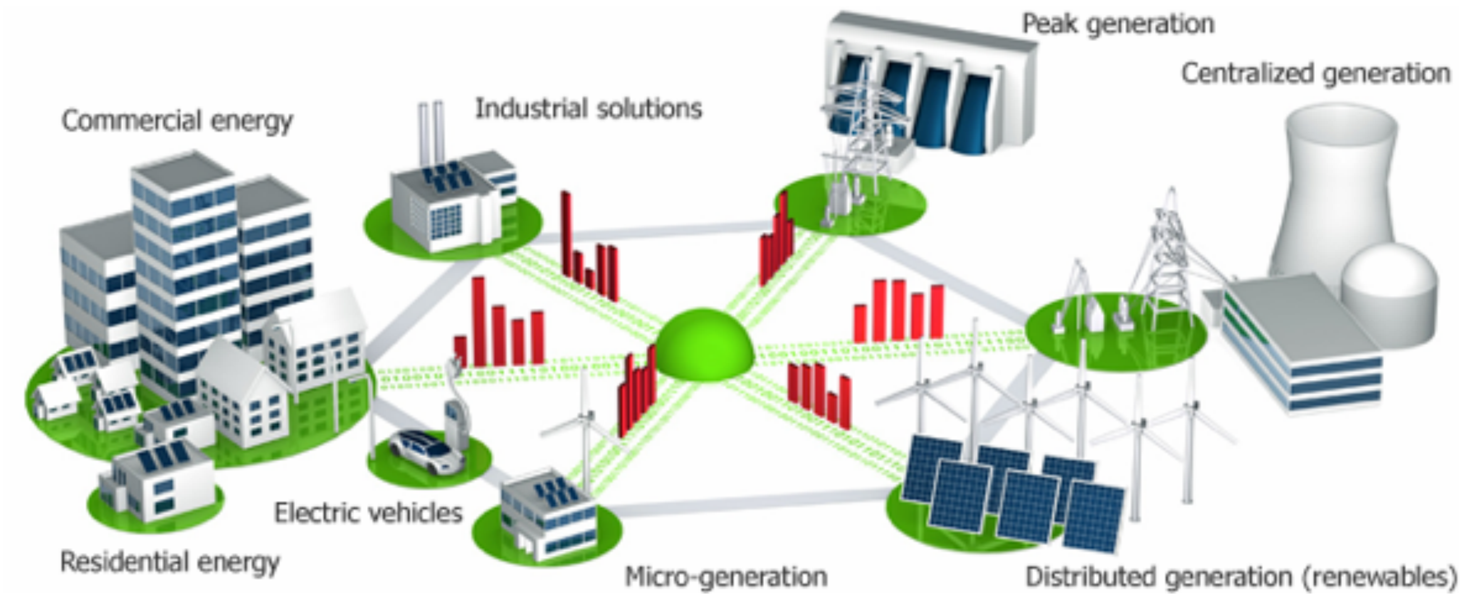
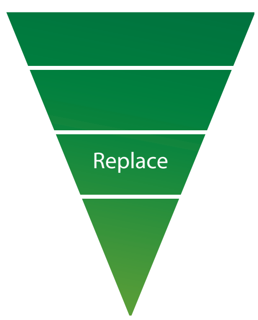


FIGURE 15 Depiction of a smart-grid system. The smart-grid better integrates multiple elements of the power infrastructure.

- Increased use of digital information and controls technology to improve reliability, security, and efficiency of the electric grid
- Dynamic optimization of grid operations and resources, with full cyber-security
- Deployment and integration of distributed resources and generation, including renewable resources
- Development and incorporation of demand response, demand-side resources, and energy-efficient resources

There are many potential benefits of utilizing smart-grid, but those most exciting for the Energy Transition Plan vision are the ability for users to communicate with the grid, thus improving energy demand response and increasing energy efficiency, and the ability to better integrate and deploy renewable energy

REPLACE HIGH CARBON ENERGY SOURCES WITH LOWER CARBON SOURCES



Maximize switching to alternative, cleaner fuels (subject to availability, technical, and regulatory constraints)

The T.B. Simon Power Plant is a co-generation plant that produces steam and electricity for campus. The plant currently uses coal, natural gas, and biomass as fuel.

Due to its low cost, coal is the primary fuel used at the plant at this time. Coal, however, also is the largest contributor to GHG emissions and air emissions that impact health. Due to conservation efforts and increasing the use of natural gas, the power plant has reduced coal use by 28% since 2006. The committee believes that to meet the emissions reduction goals in the short term with current technology, the power plant must minimize the use of coal and increase the use of natural gas.

Natural gas can be used in all of the boilers, and MSU is permitted to use biomass in boilers 1, 2, 3, and 4. Increasing the use of biomass can help MSU reach a significant portion of its renewable energy goal in 2015.

The power plant boilers are set up as "plug and play" equipment, meaning that existing boilers can be switched out for other equipment. As technology emerges, newer, no emissions/low emissions fuels or equipment that decrease emissions may be switched with the current technology, creating more viable options in a central plant setting as the university moves toward renewable energy.

FIGURE 16 Inside the T.B. Simon Power Plant

No Coal

The committee specifically discussed having a goal or strategy that utilized the dual functionality of the existing four boilers to burn natural gas instead of coal so as to eliminate or minimize the use of coal in the near future. The business-as-usual scenario replaces two of the four boilers in 2025 and the other two in 2040 with natural gas turbines, when the current boilers reach the end of their planned useful life. The committee recognized that the power plant has the technical capability to eliminate the burning of coal in FY2013, but refrained from recommending a 'no coal' policy statement due to the desire to maintain fuel flexibility and concerns about the impact of rising natural gas prices[1] on future energy conservation and renewable energy investments.

The committee agreed that the university should prioritize energy conservation measures. Reduced energy demand saves money that can be reinvested for future energy needs. The committee also recommends burning 100% natural gas in boiler 3 to eliminate the need for a $24 million power plant investment in emissions controls due

[1] Based on U.S. Energy Information Administration forcast.

to recent Boiler MACT regulations.

Fuel switching beyond boiler 3 is necessary to meet the recommended short term emissions targets. Using the maximum amount of natural gas throughout the power plant would reduce GHG emissions up to 50% and individual air pollutants by 66-99% (assuming energy conservation and some additional supply side strategies). However, it also would add approximately $3.5-$6 million annually in gas costs , which would limit the funds available for re-investment into energy conservation measures and renewable energy infrastructure.

The goals and vision are set such that MSU would eliminate all fossil fuels over time. To meet the emission targets in the near term, the university must go beyond 100% natural gas in boiler 3 in concert with energy conservation measures and implementing renewable energy infrastructure until larger capacity renewable energy options are available.

FIGURE 17 Wind turbines churn in a wind farm

Purchase green power

Another method for reducing emissions and increasing renewable energy is to purchase green power from local utilities companies. The state of Michigan requires utility companies to have 10% of their energy come from renewable resources by 2015. MSU purchases a small amount of energy from two local utilities, the Lansing Board of Water and Light and Consumer's Energy for service to the south campus farm area. MSU T.B. Simon Power Plant has an electrical interconnection with Consumer Energy for back up electrical power for a portion of main campus. Utilities get renewable energy from wind, anaerobic digestion, solar, and hydroelectric projects.

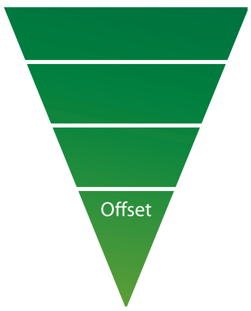
Another option may include purchasing green energy via open access. Retail Open Access allows customers such as MSU to contract with an alternative energy source directly versus purchasing energy from a utility company.

An added benefit of purchasing power is greater efficiency at the power plant. In a cogeneration plant, the system is most efficient when the demand for steam and electricity are congruent. However, the demand for electricity is out-pacing the demand for steam, thus decreasing plant efficiency. Green power (electricity) could be purchased to bring the steam and electricity production at the plant into balance and thus have a higher plant efficiency. This also would contribute to a significant amount of the renewable energy target for 2015.

Create a large-scale renewable project

Renewable energy may be incorporated into the earlier strategy by implementing more aggressive building energy standards; however, another method of increasing renewable energy is to create a large-scale renewable project such as a wind or solar farm. Just as a centralized power plant helps the university realize efficiencies, a centralized renewable energy source also would likely be more efficient than several decentralized projects.

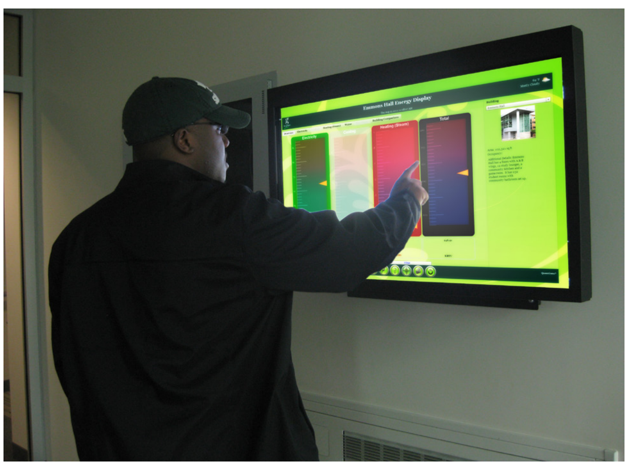
OFFSET EMISSIONS THAT CANNOT BE AVOIDED, REDUCED, OR REPLACED



Utilize carbon offsets

Carbon offsets benefit the global environment when organizations either create projects that capture emissions or invest in projects that increase the world's supply of renewable energy. Purchasing offsets can help developing economies grow around the world. MSU has used offsets in the past as part of its involvement with the former Chicago Climate Exchange (CCX). Through participating in the CCX, MSU helped shape offset protocol and definitions, as well as identifying opportunities to receive offsets through donations and gifts. Although the Chicago Climate Exchange is no longer active, MSU can continue to use offsets to address remaining emissions within the system.

FIGURE 18 An MSU staff member reviews real time energy data on the energy dashboard in Emmons Hall.



Educate the community on MSU's energy system and continue behavior change for energy conservation

Energy education also should continue in order to help the MSU community understand and participate in working toward the goals of the Energy Transition Plan. Campus behavior studies in 2008 showed that students had little understanding of MSU's energy infrastructure or its impacts. Building reports confirm that many faculty and staff still do not practice energy conservation behaviors. Education alone will not produce the changes needed; however, it is a critical component to the culture change needed to make the Energy Transition

Plan work. Since 2008, the Environmental Steward Program has worked with department representatives across campus to educate staff, faculty and students and promote behavior change. In addition, the Energy Educator Program was created to focus on helping people understand how they impact the energy systems in their buildings. Both programs have helped reduce energy use in buildings. Strengthening existing programs and creating new ones will continue to educate the campus on energy conservation behaviors and promote behavior change.

GOAL 2

INVEST IN SUSTAINABLE ENERGY RESEARCH AND DEVELOPMENT

The renewable energy and GHG emission targets in this plan assume that not only will new energy technologies become available in the future, but also that MSU will contribute actively to the development and demonstration of these new technologies, and sustainable energy will become an integral component of the Boldness by Design initiatives and the Land-grant/World-grant mission.

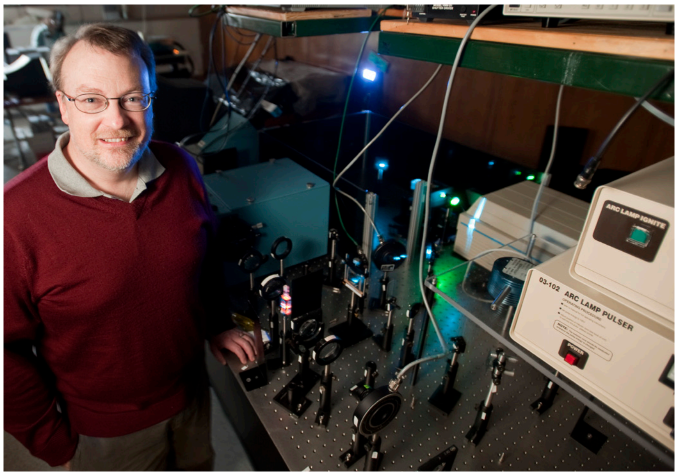
The combination of world-class researchers, energy infrastructure, and involved student body provides an ideal opportunity for the university to assume such a leadership role in sustainable energy systems research.

FIGURE 19 Dr. Steve Safferman, researcher with the Anaerobic Digester project, which leveraged research, operations, and students to develop a business plan for a commercial scale 0.5 Megawatt digester on campus. In addition to creating energy to power South Campus buildings, the digester uses food waste from MSU dining halls to make energy, thus reducing waste to landfill.

Recommended Strategies:

- **Promote sustainable energy research by using the campus as a living, learning laboratory for developing, evaluating and demonstrating new technologies**
- **Build on well-recognized sustainable energy research programs by aggressively seeking expertise and sources of funding**
- **Systematically invest a portion of energy costs and cost savings in sustainable energy demonstration projects on campus**
- **Streamline facilities, policies and systems to enhance cross-disciplinary, cross functional collaboration among academic units, faculty, staff and students**

FIGURE 20 Chemistry Professor James McCusker adjusts a laser beam as part of his research to improve solar panel technology.



Promote sustainable energy research by using the campus as a living, learning laboratory for developing, evaluating and demonstrating new technologies

The Boldness by Design strategic imperative has set the framework for MSU to move from a Land-grant to World-grant university. One of the pillars of Boldness by Design is to Increase Research Opportunities. As MSU leaders define focal areas for research, a natural area of emphasis is sustainable energy. MSU can leverage its existing world-class faculty and research programs to create demonstration projects that show leadership, educate students and shape policy.

The committee recommends that MSU leverage its research capabilities and campus infrastructure to use the campus as a living/learning laboratory to develop solutions to its most pressing energy challenges. This will put MSU on the leading edge of making change. Several academic/operations partnerships already exist; however, the Administration could further encourage and utilize these partnerships.

Furthermore, once demonstration projects are proven successful, solutions should be operationalized on MSU's campus. An example of this type of partnership would be the development of the anaerobic digester turning animal waste into usable heat, electricity and other valuable products. Researchers worked with staff and students to evaluate the construction and operation of a commercial scale digester. After determining that this was a viable technology for MSU, construction of the anaerobic digester is being proposed to the Board of Trustees in 2012. The renewable energy produced by the anaerobic digester would be used to fuel buildings on south campus.

Build on well-recognized sustainable energy research programs by aggressively seeking expertise and sources of funding

Advancing MSU's position in the renewable energies field will require the university to actively pursue additional opportunities and partnerships to promote and build on existing alternative energy research.

FIGURE 21 Grain crops from MSU AgBioResearch. These grains will be used for biofuels.

Already, faculty and students are involved in interdisciplinary research in agriculture, plant science and engineering to solve complex problems in converting natural materials to energy, for automotive and other uses:

- The MSU Bioeconomy Institute opened in March 2011 as a 138,000-square-foot professional research and development facility where MSU scientists conduct research, provide educational and outreach programs, and facilitate private sector research by start-up companies, early stage entrepreneurs, and embedded researchers from larger corporations. The institute is supported in part by interest from a $5.2 million community endowment fund raised by the Community Foundation of the Holland/Zeeland Area and a $3.4 million grant from the Michigan Strategic Fund.
- AgBioResearch (formerly the Michigan Agricultural Experiment Station) engages in innovative, leading-edge research in the areas of food, natural resources and energy. It relies heavily on close partnerships and collaborations with MSU Extension, six MSU colleges, federal and state agencies, commodity groups and other key stakeholders; and exceptional legislative support to fulfill its mission. AgBioResearch projects are funded through state, federal and private funds. In Michigan, state contributions represent more than 80% of the total AgBioResearch annual budget. Michigan commodity organizations contribute research funds to improve production, processing and marketing of their respective products, and foundations and industries contribute funds toward basic research.
- In September 2011, a consortium between Michigan State University, Lakeshore Advantage, Prima Civitas Foundation, and the New North Center received $580,000 in U.S. Economic Development Administration funding plus $500,000 from the Michigan Economic Development Corporation to create a "Proof-of-Concept Center for Green Chemistry Scale-up." MSU is using the grant to operate the site, offer support services to entrepreneurs, assist client firms in obtaining U.S. Department of Agriculture BioPreferred designations, recruit

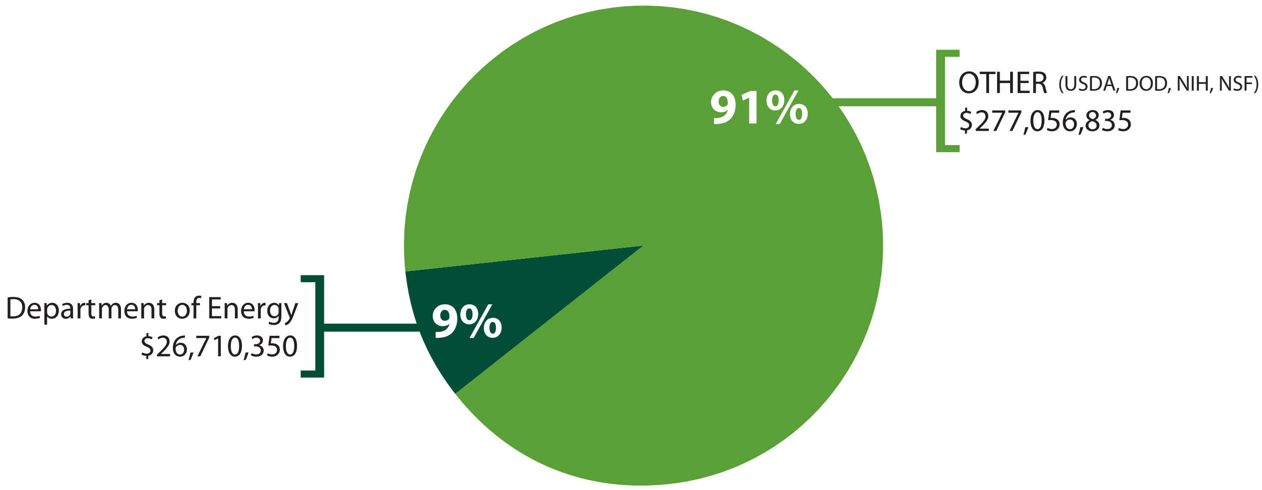
green-technology incubator occupants and more.

- The Great Lakes Bioenergy Research Center (GLBRC) is one of three national centers funded by the U.S Department of Energy to conduct transformational biofuels research. It is led by the University of Wisconsin-Madison, in close partnership with MSU and other universities, to explore scientifically diverse approaches to converting various plant feedstocks — agricultural residues, wood chips, and nonfood grasses — into liquid transportation fuels. In addition to its broad range of research projects, the GLBRC is also collaborating with agricultural researchers and producers to develop the most economically viable and environmentally sustainable practices for bioenergy production.
- The Energy and Automotive Research Laboratories at MSU's College of Engineering opened in 2007 to identify ways to realize greater fuel efficiency, determine how to collect waste heat and convert it to electricity and work to develop new bio-based fuels. Funding for the lab comes in part from a $2 million U.S. Department of Energy grant, as well as from individual and corporate

FIGURE 22

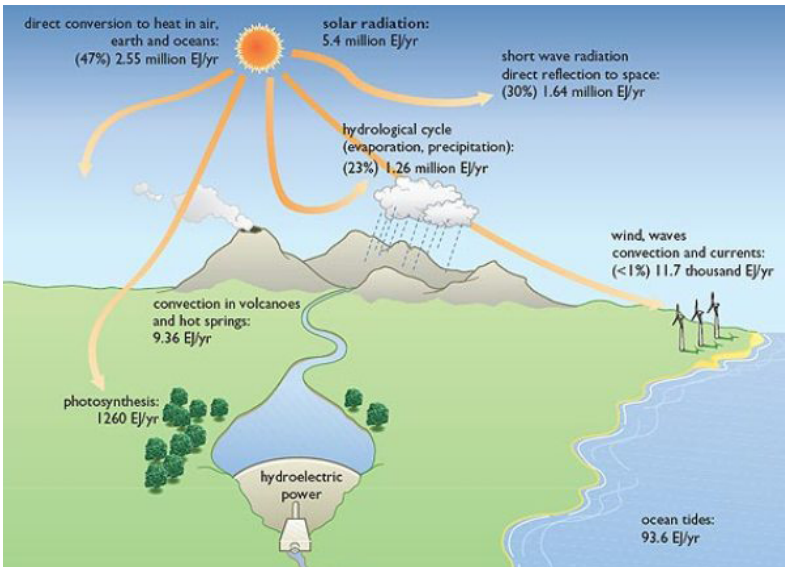
MSU was awarded more than $300 million in research revenues from federal agencies in FY 2011. The Department of Energy, which would likely be the main source of grant funds for alternative energy research, accounted for just fewer than 9% of the funds. Research funds cannot be used for university operating expenses. However, increasing the number of research grants received for alternative energy development and demonstration will create more options for incorporating renewable energy into MSU's energy infrastructure.

Federal Research Grants Awarded for 2011



Total: $303,767,185
Source: Office of the VP for Research and Graduate Studies

FIGURE 23 Potential renewable energy resources



donors, including the Richard H. Brown Foundation, Consumers Energy Foundation, Ford Motor Co. Fund, General Motors Corp., Hallenbeck Construction Co. Inc., Roy H. and Dawn I. Link, James B. McKeon, and John D. and Dortha J. Withrow, the MSU Provost's Office and the College of Engineering.

Clearly, MSU already has a solid and growing foundation in alternative energy research. Building on these efforts will shorten research and development time and better position the university to take advantage of new opportunities.

The federal government's, and to a more limited extend state government's, primary method for encouraging the insertion of new technology lies in two programs: (1) tax-based incentives (credits, deductions) and (2) grants. Only the second program is relevant to Michigan State University. To effectively pursue and secure energy grants it is advisable to have a team assigned to that task rather than to rely on ad hoc activities since the latter tends to lead to missed opportunities and uneven results.

By focusing alternative energy research projects in accordance with the Energy Transition Plan, grant writing teams could be more successful in accessing funds. Over time, successful grant projects in alternative energy will help MSU build a world-class program in which to leverage additional opportunities.

Systematically invest a portion of energy costs and cost savings in sustainable energy demonstration projects on campus

In order to facilitate a smooth long-term transition from fossil-based fuels and to make MSU a world-leader in renewable energy science and technology, the committee recommends the university annually invest at least 5% of its energy procurement budget into production infrastructure for renewable energy resources. Possible infrastructure projects may include an anaerobic digester, biofuel production facilities, photovoltaic arrays, a geothermal power plant, or wind turbines. These facilities will enable us to hedge against future rises in fossil fuel prices, but much more importantly will act as continuously evolv-

24 FIGURE Renewable energy resources

ing research and teaching laboratories. This will establish MSU as an international leader in renewable energy research, allowing us to better compete for large external research grants. Furthermore, this investment will allow us to educate our students in the creation and use of tomorrow's energy technology.

Streamline facilities, policies and systems to enhance cross-disciplinary, cross functional collaboration among academic units, faculty, staff and students

As faculty, staff, and students work together to pilot sustainable energy projects, systems should be streamlined to ensure timely implementation of successful projects. The university also should promote an entrepreneurial culture that rewards informed risk taking and timely decision making. As a result, the time it takes to reach decisions is decreased and projects move faster. MSU then can more favorably position itself to partner with external entities on sustainable energy research.

Conceivably, the faster MSU can create and pilot new sustainable energy solutions, the faster it can reach the physical campus targets. Furthermore, the university would demonstrate research leadership and fulfill its World-grant outreach mission.

GOAL 3

BECOME AN EDUCATIONAL LEADER IN SUSTAINABLE ENERGY

Great universities leverage their strengths to shape the future in areas of national and global importance. There is no doubt that MSU is a great university.

The *Shaping the Future* design principles, using Boldness by Design as their foundation, has repositioned MSU as a 21st century academic powerhouse and an economic engine for the region and the state during a time of considerable financial constraints. It has been a uniquely powerful process, demonstrating how an entrepreneurial-institutional culture can serve as a lever to leap forward during times when most institutions retrench and hunker down.

A Land-grant university has a mission beyond educating students and developing research. It also plays an important role in applying its knowledge to improve the quality of life for its local, regional and national communities. As we move toward our goal of renewable sustainable energy on campus, we will be improving the lives of our campus community as well as the communities around us.

FIGURE 25 Crop and soil scientist Doo-Hong Min is a forage specialist at MSU's Upper Peninsula Experiment Station.

Recommended Strategies:

- **Educate stakeholders about MSU's long-standing commitment to and ongoing research in sustainable energy**
- **Share MSU's energy transition process and lessons learned**

Educate stakeholders about MSU's long-standing commitment to and ongoing research in sustainable energy

The vision of moving to 100% renewable energy is more achievable when the community sees MSU as a strong leader in sustainable energy development and application.

MSU has made several achievements in energy to date, including reducing energy use and GHG emissions, and increasing renewable energy through a geothermal system for the Life Sciences addition and solar panels on the MSU Surplus Store and Recycling Center. However, many stakeholders are unaware of MSU's contributions and as such the university may be missing out on opportunities to engage stakeholders in partnerships to support further advancements.

Communications and outreach is critical to our success. MSU must share our story and develop strong community partners through strategic and comprehensive external communications and outreach to inform the public as well as policy makers about the university's contributions and progress in sustainable energy development and use.

This type of outreach will require a cross-functional approach to communications and outreach, with a cohesive message about energy told by the entire university.

FIGURE 26

WBI Director of Midwest Energy Policy Analysis Gary Radloff speaks at the 2010 UW Energy Hub Conference held on November 5, 2010 at the Monona Terrace in Madison, WI. Matthew Wisniewski/Great Lakes Bioenergy Research Center

Share MSU's energy transition process and lessons learned

As organizations struggle with energy challenges world wide, MSU's inclusive, systematic approach could become a model for organizations and communities. MSU has the population and infrastructure of a small city. If our campus can successfully reduce emissions and move to renewable energy, we can become an example in how to do this in many communities.

The Association for the Advancement of Sustainability in Higher Education (AASHE) believes that leadership for sustainability initiatives must come from higher education. MSU is the ideal place to demonstrate energy solutions that can be applied broadly and across communities. The campus can be an incubator for new technologies, outreach, engagement and education.

As we work toward our vision, MSU must share its processes and outcomes with the greater community through conferences, workshops, community dialogue and other means.

IMPLEMENTATION & REPORTING

Implementation

Upon acceptance of this plan, the Administration will be responsible for implementing the three goals. A team will be formed to put strategies into action to achieve the goals. The team should be inclusive of the university's major stakeholders – operations staff, academic staff, and students.

This team should pay particular attention to funding options associated with the implementation of the strategies. The Energy Strategies model allowed for a broad evaluation of costs, but the team will need to think through cost impacts to departments at a granular level. For example, there are a mix of general fund units and auxiliary units. General fund units receive funds from tuition whereas auxiliary units generate their own funds from their business activities. Consideration must be made if implementation strategies impact auxiliary units' business activities.

Fiscal planning generally takes place a year prior to the calendar year. Thus, implementation of the Energy Transition Plan should begin immediately to ensure adequate planning time and resources.

It is important that an informed, evidence-based process is used to make implementation decisions. The Sustainability Visioning Group document, *A Vision for Sustainability*[2], presented to the MSU Board of Trustees in December 2011, states the importance of guiding principles such as deliberate goal setting, clear metrics, and accountability as integral to MSU's sustainability progress. As MSU works towards its vision of 100% renewable energy, it must continue to use these principles to make implementation decisions.

Reporting

As mentioned previously there will be a complete review of the Energy Transition Plan every five years. This review will consist of a thorough examination of existing and next generation energy technologies, conservation measures, behavior-based programs, planning assumptions, and goals and strategies. If MSU is on track to surpass its goals, new and more aggressive goals should be set.

In addition to the five-year review, there will be an annual report to the Board of Trustees and MSU community on progress toward the goals.

[2]*bespartangreen.msu.edu/documents/2011sustainabilityvisioningreport.pdf*

CONCLUSION

Achieving the Goal and Raising the Bar

On May 25, 1961, President John F. Kennedy said in an address to a special joint session of Congress: "I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth."

At the time of this announcement, the Soviet Union had already sent a man into space and although the United States had made significant progress, they were not yet setting the pace for the space race. In a speech at Rice University, Kennedy said:

> *"We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win, and the others, too.*
>
> *It is for these reasons that I regard the decision last year to shift our efforts in space from low to high gear as among the most important decisions that will be made during my incumbency in the office of the Presidency."*

What followed was a renaissance of ideas and action. In 1969, not only did the United States man a successful mission to the moon, but as a result, several technological spinoffs were created that have improved quality of life throughout the world.

Fifty years later, we are not looking to the stars, we are looking under them. We are looking to protect our air, land and water for the immediate benefit of us all as well as for coming generations.

The challenges that face our planet are great and as a World-grant leader in higher education, we must lead the resolution of this issue.

MSU has set its bold vision of moving to 100% renewable energy. Although not all paths are certain at this time, the university must commit, just as the United States did in 1961, to achieving a monumental goal. It is likely that the journey will lead to the development of new technologies, new ideas and new benefits to those around the world.

With a clear vision, alignment of resources and a commitment to work together, we can achieve our vision of a renewable energy future – providing a better future for MSU, its community and the world.

GLOSSARY

Alternative Energy	Any form of energy that does no come from fossil fuels; often is renewable. Alternative energy is clean: has few or zero carbon emissions and produces few toxic by-products
Biomass/Biofuel	A renewable energy source created from organic material made from plants and animals (microorganisms). Examples of biomass fuels are wood, crops, manure, and some garbage
Capacity, electric	The maximum amount of electric charge that can be stored.
Capacity, heat	The measurable physical quantity that characterizes the amount of heat required to change a substance's temperature by a given amount. (Source: http://en.wikipedia.org/wiki/Heat_capacity)
Capital Investment	Funds invested in a firm or enterprise for the purposes of furthering its business objectives. Capital investment may also refer to a firm's acquisition of capital assets or fixed assets such as manufacturing plants and machinery that is expected to be productive over many years. (Source: http://www.investopedia.com/terms/c/capital- investment.asp#axzz1h6Mg25Y6)
Carbon Offsets	A reduction in emissions of carbon dioxide or greenhouse gases made in order to compensate for or to offset an emission made elsewhere.
Coal	A combustible black rock that is a fossil fuel created from the remains of plants that lived and died about 100 to 400 million years ago when parts of the Earth were covered with huge swampy forests. Coal is a non-renewable energy source.
Digester (Anaerobic)	A machine that turn today's organic material (plants, food waste, animal wastes, etc.) into natural gas. This process replaces waiting for millions of years for the gas to form naturally.
Energy Storage	Energy storage is accomplished by devices or physical media that store some form of energy to perform some useful operation at a later time. A device that stores energy is sometimes called an accumulator. (Source: http://en.wikipedia.org/wiki/Energy_storage)
Firm Capacity	The amount of energy available for production or transmission which can be (and in many cases must be) guaranteed to be available at a given time.

Geothermal	A renewable energy source generated from heat from the Earth's core. This heat is recovered as steam or hot water and used to heat buildings or generate electricity.
Green Power/Energy	The EPA defines green power as electricity produced from solar, wind, geothermal,biogas, biomass, and low-impact small hydroelectric sources.
Greenhouse Gases	Gases that trap heat from the sun's radiation in the atmosphere. Some greenhouse gases, such as carbon dioxide, occur naturally and are emitted to the atmosphere through natural processes. Other greenhouse gases, such as carbon dioxide, methane, nitrous oxide, and fluorinated gases, are created and emitted solely through human activities.
LEED	Leadership in Energy and Environmental Design is an internationally-recognized green building certification system developed by the U.S. Green Building Council.
Natural Gas	A non-renewable energy source, the main ingredient in natural gas is methane gas. Natural gas is tiny bubbles of odorless gas created from the remains of plant and animal decay from millions of years ago.
Photovoltaic Arrays	A system which uses one or more solar panels to convert sunlight into electricity.
Reliability (energy)	An energy source is considered reliable if it can be used to generate a consistent electrical output and is available to meet predicted peaks in demand.
Renewable Energy	Energy that comes from natural resources such as sunlight, wind, tides, and geothermal heat, which are naturally replenished.
Retro-/re-commissioning	Evaluates existing building and mechanical systems to determine whether they are performing as required to meet the requirements for the current intended use of the facility.
Smart Grid Technology	Refers to a class of technology people are using to bring utility electricity delivery systems into the 21st century, using computer-based remote control and automation. These systems are made possible by two-way communication technology and computer processing that has been used for decades in other industries. (Source: http://energy.gov/oe/technology-development/smart-grid)
Solar Energy	Renewable energy that comes from the sun's rays (solar radiation) that reaches the Earth and can be converted into other forms of energy, such as heat (thermal) and electricity.
Sustainable Energy	Energy that meets the needs of the present without compromising the ability of future generations to meet their needs. Sustainable energy sources include all renewable energy sources as well as technologies designed to improve energy efficiency.
Thermodynamics	A process of energetic change within a system, generally associated with changes in pressure, volume, internal energy, temperature, or any sort of heat transfer.
Wind Energy	A renewable energy source used to generate electricity with the use of wind machines or turbines.

Appendices

A. Black and Veatch Report

B. Community Outreach Summary Report

C. Summary of External Committee Comments

MICHIGAN STATE UNIVERSITY NEXT GENERATION ENERGY STRATEGIES

30 November 2010

B&V Project Number 163782
B&V File Number 14000.0000

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1.0 Introduction

1.1 Integration of Energy Technologies

Recognition of the interrelationships of the systems, which make up the campus energy infrastructure, is essential for understanding the full effects of applying any new energy technology and its integration into the campus energy system. This is because no energy technology operates independently. Any energy technology actually operates within a chain of cascading systems which begin with an energy source or fuel and end by serving an energy load, such as air heating or room lighting in a building. Each energy system therefore usually does one of two things: it either converts energy from one form to another, or it transports the energy from one place to another.

The word “usually” is used, because there is a third function which also may be utilized, and that is storing energy in a location. Today energy storage is less common and the technology is less developed than technologies for energy conversion and transport. Current energy systems are essentially “just in time delivery” systems, meaning that no energy storage is applied. However, this is changing, and a section of the report on energy storage covers the current technology. Storage is not currently a part of the University campus energy infrastructure.

Any energy technology to be applied to the University campus will be applied typically by inserting it into the appropriate place in the campus energy infrastructure. The insertion of some energy technologies may require minimal changes to the existing campus energy infrastructure while others may require major alterations. Knowing the degree of the modifications required to the existing energy infrastructure imposed by the application of any new energy technology is critical to realistic evaluation of that new technology.

To begin to understand the importance of recognizing the cascading of energy systems and how they interrelate, it is beneficial to begin with the end in mind. That would be accomplished by describing the energy loads found on the University campus.

Campus Energy Loads and Systems to Serve the Loads

All energy generated, converted, and transported is done to ultimately serve energy loads. For this exercise, energy loads are those required to provide end products, such as some desired condition and movement of environmental air, space lighting and equipment operation, water temperature and delivery, and so forth. For the campus, these energy loads are typically listed as follows:

- Building ventilation
- Building heating
- Building air conditioning
- Building domestic water heating
- Building food cooking
- Building food and other refrigeration and freezing
- Building lighting
- Building computers and other occupant used equipment
- Building heavy equipment
- Building laboratory equipment sterilization and heating
- Building laboratory countertop burners
- Site lighting
- Site electricity to operate outdoor equipment

Later in this report the magnitude of the energy loads, their projected growth, and the capacity of the existing energy infrastructure to serve the loads are addressed. For now, the basic major energy systems and fuels serving the loads are simply added to the list of loads, typically as follows:

- Building ventilation – electricity
- Building heating – steam
- Building air conditioning – electricity and chilled water
- Building domestic water heating – steam and natural gas
- Building food cooking – natural gas
- Building food and other refrigeration and freezing – electricity
- Building lighting – electricity
- Building computers and other occupant used equipment – electricity
- Building heavy equipment – electricity and compressed air
- Building research and medical equipment sterilization and heating – steam
- Building laboratory countertop burners – natural gas
- Site lighting – electricity
- Site electricity to operate outdoor equipment – electricity

Many of the energy systems immediately serving the loads listed are themselves served by other energy systems, especially those energy systems which generate electricity, steam, chilled water, and compressed air. The electricity serving most of the electric loads and the steam serving all of the thermal loads of Michigan State University is generated on campus at the T. B. Simon Power Plant.

The T.B. Simon Power Plant is a cogeneration plant simultaneously generating both electricity and steam from a common fuel source. The common fuel source is usually coal, but occasionally natural gas is also used. Basically the fuel is converted to heat in a boiler which produces high pressure steam, and the steam is then converted to produce both high voltage electricity and low pressure campus district steam in a steam turbine generator. This is the essence of central power plant cogeneration process, and it is described in more detail below. The cogeneration system converting a common fuel to electricity and steam may be simply depicted as illustrated in the figure below.

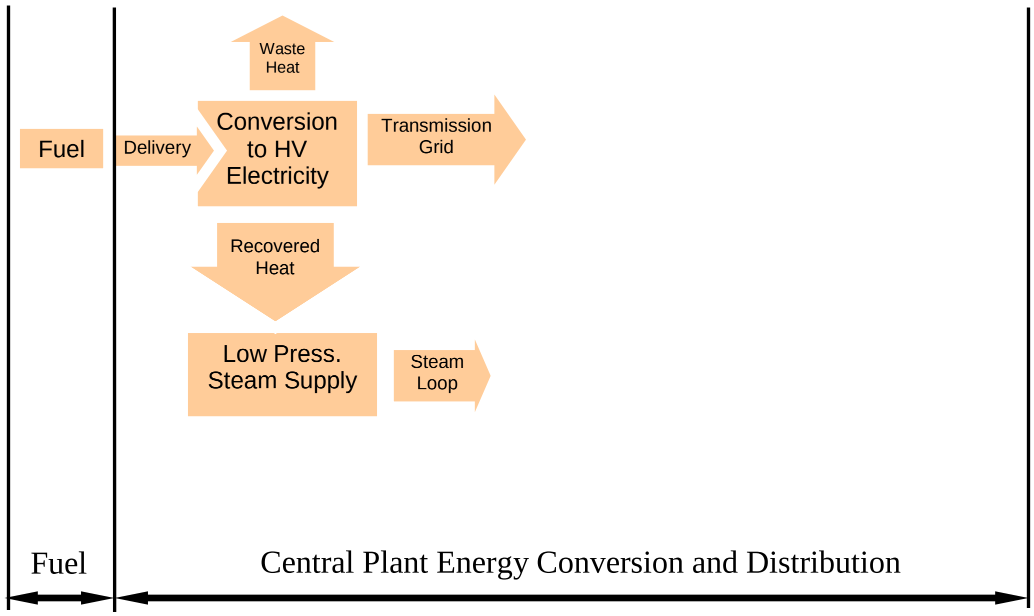


Figure 1-1. Central Plant Portion of Campus Energy Infrastructure

This figure of the T.B. Simon Power House shows essentially the first stages of the cascading of energy systems serving the University campus energy loads.

There are subsequent or intermediate conversion processes and distribution networks which are summarized next. One of the intermediate energy conversion processes widely used on campus is that which produces chilled water for building air conditioning. For the campus, chilled water is produced mostly though the use of steam absorption chillers. The steam absorption chillers use the steam generated at the T.B. Simon Power Plant. The steam is also widely used for building heating.

While the steam is being used to convert its energy to chilled water, the high voltage electricity generated at the powerhouse is transmitted to individual buildings where it is transformed to low voltage and distributed for use in energizing pumps, fans, air conditioners, small chillers, and other heavy equipment, building lighting, and plug loads.

The existing system of cascading energy conversion and distribution processes serving the campus is complicated. However, some of the basic infrastructure can be illustrated by diagramming typical major systems from fuel delivered to the campus to campus energy loads. Among the most typical energy loads are those for building cooling and building lighting. These loads also are serviced though some of the more complicated cascades of energy conversion systems and distribution systems. The basic campus energy infrastructure to serve building cooling loads from the campus steam loop followed by chilled water loops and air handling equipment, and building lighting and plug loads from the campus power transmission grid and distribution system can be illustrated in the figure below.

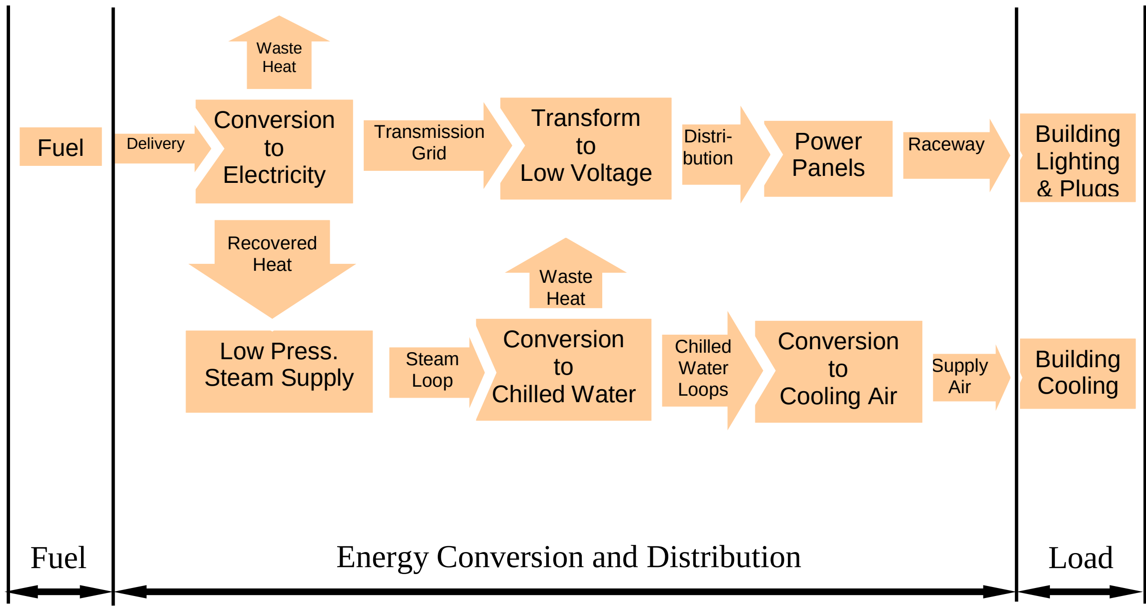


Figure 1-2. Basic Campus Energy Infrastructure Diagram

Notice that the boxes and arrows on the left are identical to those in the first figure showing only the T.B. Simon Power Plant. The new boxes and arrows to the right represent the intermediate energy conversion and distribution systems leading up to and finally including the building energy loads on the far right.

Certainly there are other energy loads, such as electric chillers, air conditioners, air compressors, hot water converters, sterilizers, and others all served through the major systems. However, in an effort to simplify the diagram to more clearly illustrate the concept of cascading energy conversions and distributions, these are omitted for now.

Figures like these will be used later to illustrate the integration of various energy technology options, identifying any modifications which will be needed to the existing energy infrastructure. These diagrams will then provide a basis for a comprehensive comparison of one optional technology to another.

As shown in the first two figures, there are the primary energy conversion processes in the T.B. Simon Power Plant, followed by intermediate cascading energy conversion and distribution processes, and those are followed by the campus building energy loads. This report is divided to focus on each of the three areas as summarized under the next three headings.

1.2 Central Plant

The T. B. Simon Power Plant is a major part of the campus energy infrastructure, the beginning of all the major energy conversion and distribution processes on campus. This report addresses the University's existing cogeneration assets at the power plant. The main issue is that the existing plant is mostly coal fired, and environmental regulation may make it increasingly costly for the University to continue to burn coal. Alternates, like switching to natural gas as the primary fuel, replacing the boilers to enable the burning of biomaterials, or adding NOx abatement and other back end controls, are also expensive. These issues and alternatives for central plant electricity and steam generation are discussed as the central plant strategy.

1.3 Distributed Generation

The report addresses energy options beyond those within the boundaries of the central plant. This introduces the second strategy area which is "Distributed Generation". This strategy area begins with listing and describing options to replace the burning of coal at the central plant. These alternatives include solar photovoltaic (PV), wind, micro turbines, fuel cells, etc. The report screens options to provide those most appropriate technologies for the University.

1.4 Demand Side Management and Smart Grid

The campus energy systems include central plant generation elements, distributed generation elements, and then load or demand side elements. Near the end of the cascading energy conversion processes, there may be demand side management strategies including chilled water thermal energy storage (TES), peak demand limiting controls for building cooling systems, solar water heating, and even small scale solar PV generation. For the multitude of these systems, the implementation of a "Smart Grid" may offer a technology to tie it all together. For the University the appropriate technology may be what is called a "microgrid" to manage both central and distributed generation elements on the supply side and selected users on the demand side to optimize the control of all energy—generated, converted, and consumed.

The next section will focus attention on the existing conditions at the campus, including the magnitude of energy loads, growth projections, and the conditions in and around the central plant to handle those loads.

2.0 Existing Conditions and Campus Growth

The Michigan State University campus is a very large campus of 5200 acres. Most of the buildings are concentrated on the main campus which occupies the northern third of the total acreage. The southern two thirds of the campus are mostly agricultural lands with some buildings located in small clusters surrounded by open spaces. The buildings concentrated on the northern third are served with steam and electricity co-generated at the T.B. Simon Power Plant located at the southern edge of the main campus. The main campus buildings use steam for space heating, domestic water heating, and for cooling through the use of steam absorption chillers. Most of the chillers are located in individual buildings, but there is one district chilled water system with a total steam absorption chiller capacity of 12,000 tons serving several buildings. In total, the capacity of the steam absorption chillers on main campus is 30,000 tons. Between building heating systems and steam absorption chilled water systems, the buildings on main campus impose a steady demand for steam from the central plant all year round. The campus is therefore highly suitable for service by a cogeneration plant.

The T.B. Simon Power Plant has sufficient capacity to serve all the steam and electricity demands for all the campus buildings in the northern third section, and there is sufficient steam and electricity distribution capacity to deliver the energy. Some of the buildings are also served by natural gas for specific building needs, such as cooking and laboratory operations, but this represents a very small portion of the total energy demands of the buildings on main campus. The campus demands for steam and electricity from the central power plant are discussed in the next section.

2.1 Summary of Existing and Future Campus Energy Demands

Most of the energy serving the campus has historically come from the T.B. Simon Power Plant through its cogeneration of steam and electricity. The campus energy demands for central plant capacity are driven by the size of the buildings, the energy intensity of the facilities, and the growth of the campus in terms of new buildings. Campus building growth over the past twenty years for buildings with electricity served by the central power plant is summarized on the following table:

Fiscal Year	Campus Utility	10 Year Increase	10 Year Increase
	sq ft	sq ft	%
90-91	17,308,456	2,183,456	14.44%
91-92	17,389,931	2,263,931	14.97%
92-93	17,471,406	2,075,406	13.48%
93-94	17,433,763	1,673,763	10.62%
94-95	17,396,120	1,636,120	10.38%
95-96	17,385,980	1,625,980	10.32%
96-97	17,375,839	1,467,839	9.23%
97-98	17,856,267	1,599,588	9.84%
98-99	18,336,694	1,731,336	10.43%
99-00	18,378,524	1,421,617	8.38%
00-01	18,420,354	1,111,898	6.42%
01-02	18,636,726	1,246,795	7.17%
02-03	18,853,098	1,381,692	7.91%
03-04	19,079,808	1,646,045	9.44%
04-05	19,306,518	1,910,398	10.98%
05-06	19,365,138	1,979,159	11.38%
06-07	19,564,230	2,188,391	12.59%
07-08	19,763,321	1,907,055	10.68%
08-09	19,801,735	1,465,041	7.99%
09-10	19,997,178	1,618,654	8.81%

Table 2-1. Growth of Campus Buildings with Central Plant Electricity

According to the values in this table, campus building construction over the years has been quite aggressive, adding on the order of 2,000,000 square feet every ten years. Campus growth in terms of square footage has been less in more recent years, but the buildings which have been added have been more energy intensive.

Traditionally, campus energy has been measured by the fuel used at the T. B. Simon Power Plant. The following graph shows how power house energy usage has grown with campus building expansion. This graph shows energy use only for the past nineteen years because the current fiscal year data is not available at this time.

Fiscal Year	Power Plant Fuel Usage	10 Year Increase	10 Year Increase
	Million Btu/yr	Million Btu/yr	%
90-91	4,736,000	948,000	25.03%
91-92	4,642,000	924,000	24.85%
92-93	4,643,000	980,000	26.75%
93-94	5,082,000	1,150,000	29.25%
94-95	5,237,000	1,310,000	33.36%
95-96	5,538,000	1,530,000	38.17%
96-97	5,400,000	1,262,000	30.50%
97-98	5,642,000	1,244,000	28.29%
98-99	5,793,000	1,310,000	29.22%
99-00	5,752,000	1,220,000	26.92%
00-01	6,058,000	1,322,000	27.91%
01-02	5,877,000	1,235,000	26.60%
02-03	6,219,000	1,576,000	33.94%
03-04	6,307,000	1,225,000	24.10%
04-05	6,344,000	1,107,000	21.14%
05-06	6,506,000	968,000	17.48%
06-07	6,559,000	1,159,000	21.46%
07-08	6,677,000	1,035,000	18.34%
08-09	6,543,000	750,000	12.95%

Table 2-2. Power Plant Energy Growth

According to the values in this table, energy usage has actually increased by greater 10-year percentages than those for the increases in campus building areas. This verifies the claim that newer buildings are using more energy than are older buildings on the campus. Newer buildings in general have had more cooling, ventilation, and air conditioning loads. Some new buildings, such as those providing research and laboratory functions, have higher energy use densities by their nature than do the simpler classroom and lecture buildings. This table demonstrates the trend in more energy intensive buildings among new buildings. Some of the energy included in the values on this table is used in the power plant for its internal processes. Internal energy used at the central power plant will be discussed later.

The steam and electricity distributed from the central powerhouse to the campus buildings is measured, and these measurements provide an accurate accounting for the energy used by the campus buildings alone. The quantification of energy used only in the campus buildings is important for evaluating the application of alternative energy generation technologies remote from the central power plant.

The campus peak demand for steam dictates how much steam generating capacity is required at the power plant. The total steam delivered over the year provides the measurement of annual thermal energy consumption. The following table shows steam demands by and annual deliveries to the campus buildings from the T.B. Simon Power Plant for the past nineteen years:

Fiscal Year	Steam Peak Demand	Steam Peak Demand	Steam Delivered	Steam Delivered
	lb/hr	lb/hr 1000sf	1000 lb/yr	lb/yr sf
90-91	495,000	28.60	1,992,673	115.13
91-92	487,000	28.00	2,021,210	116.23
92-93	520,000	29.76	1,988,144	113.79
93-94	565,000	32.41	2,133,610	122.38
94-95	510,000	29.32	1,996,837	114.79
95-96	596,000	34.28	2,190,270	125.98
96-97	565,000	32.52	2,336,253	134.45
97-98	535,000	29.96	2,409,522	134.94
98-99	602,000	32.83	2,566,532	139.97
99-00	602,000	32.76	2,448,072	133.20
00-01	640,000	34.74	2,516,930	136.64
01-02	526,000	28.22	2,537,685	136.17
02-03	646,000	34.26	2,803,598	148.71
03-04	585,000	30.66	2,608,932	136.74
04-05	638,000	33.05	2,747,212	142.29
05-06	576,530	29.77	2,890,812	149.28
06-07	537,000	27.45	2,799,349	143.09
07-08	627,380	31.74	2,780,577	140.69
08-09	627,160	31.67	2,730,807	137.91
Average		31.16		132.76
Last 5-Year increase	7.21%	3.30%	4.67%	0.86%

Table 2-3. Campus Steam Demand and Consumption Growth History

According to the values on this graph, steam demand and usage have increased over the past 20 years not only in parallel to the building growth, but also on a per unit basis. Note that steam is used for both building heating and cooling through the use of steam absorption chillers for most of the campus. This suggests that newer buildings may be demanding higher heating and cooling loads than their older counterparts.

The next table shows demand and deliveries for electricity to the campus in the same way the table above does for steam. Powerhouse electricity usage and demand are not included in either table so that the thermal and electricity demands and usages for the campus buildings alone can be presented and used for evaluation of both central plant and distributed energy generation options. For steam, the values for usage and demand were extracted directly from the Power and Water Department Annual Production Report. For electricity, the campus usage values, power plant usage values, and total University demand values, which include the power plant demand, were available from the report. Therefore, electricity demand for campus buildings alone had to be estimated. This was done by first estimating a power plant demand and then subtracting it from the total University demand. The power plant demand was estimated by dividing power plant electricity usage per month by the number of hours in the month. The campus demand was then calculated by subtracting the power plant demand from the total University electricity demand. The results were estimated values of demand for campus buildings per month. The highest monthly values were applied to each year. It is recognized that the actual power plant demand will be higher than the average value calculated, however due to the 24 hour per day nature of power plant operation, it is expected that this average value should not be much lower than the peak. It is also recognized that the peak demands for the power plant may not necessarily coincide with the campus peak demand therefore requiring a value lower than the peak. As these two conditions nearly cancel each other out, no other calculation was performed, and the values for campus demand were used as estimated. Additionally, campus annual power factor was calculated as a check of the validity of the estimate. The following table is the result:

Fiscal Year	Electricity Peak Demand	Electricity Peak Demand	Electricity Delivered	Electricity Delivered	Campus Power Factor
	MW	MW/ 1000sf	MW hrs/yr	kW hrs/ yr sf	
90-91	39.54	2.28	197,871	11.43	0.57
91-92	35.45	2.04	203,172	11.68	0.65
92-93	37.05	2.12	206,572	11.82	0.64
93-94	40.38	2.32	218,491	12.53	0.62
94-95	40.14	2.31	222,582	12.79	0.63
95-96	40.99	2.36	222,753	12.81	0.62
96-97	41.96	2.42	221,264	12.73	0.60
97-98	44.28	2.48	235,260	13.18	0.61
98-99	46.23	2.52	233,190	12.72	0.58
99-00	47.07	2.56	231,207	12.58	0.56
00-01	46.92	2.55	231,098	12.55	0.56
01-02	48.32	2.59	232,459	12.47	0.55
02-03	49.92	2.65	245,427	13.02	0.56
03-04	50.79	2.66	244,378	12.81	0.55
04-05	48.72	2.52	245,181	12.70	0.57
05-06	48.16	2.49	252,729	13.05	0.60
06-07	51.42	2.63	268,468	13.72	0.60
07-08	52.94	2.68	273,265	13.83	0.59
08-09	50.39	2.54	274,420	13.86	0.62
Average		2.46		12.75	0.59
Last 5-Year increase	-0.79%	-4.41%	12.29%	8.20%	

Table 2-4. Campus Electricity Demand and Consumption Growth History

This table shows reasonable annual power factors for a university campus validating the procedure for estimating the campus electricity demand. The table also shows a significant increase in the usage of electricity and a slight decrease in the peak demand for electricity over the past five years. One logical conclusion from these tables is that newer buildings are consuming more electricity than the older buildings, and that power generation fuel will also increase proportionally. This conclusion is in alignment with the conclusion from the first table above showing energy consumption at the power house. Another conclusion which can be drawn is that the typical high energy demand for building cooling is being served more by steam absorption chillers, which use little electricity. The result is that the increased usage of electricity serves the more even loads, such as 24 hour lighting, ventilation fans, and equipment expected in medical and research buildings.

Use of these tables to project peak demands of thermal and electrical loads requires some information about projected campus growth and some reasoning. Current plans call for an additional 400,000 gsf to be added in the next two years along with demolition plans for an equal gsf. However, the buildings being replaced are not air conditioned residences and therefore low energy users, the new buildings will be for museum, office, classroom, research, and food preparation uses. Of special note is the 170,000 gsf Cyclotron facility. These are high energy use buildings. It is expected that the Cyclotron alone will ramp up to adding a demand of 16.5 MW alone by FY 2017. Therefore, the prudent approach to estimating future demands would be to proportion demand with campus building expansion while adding Cyclotron impacts separately.

Though it has been shown that electricity usage may be projected upward at a faster rate than building growth alone, it is also expected that energy saving features will increase with new construction as a result of the growing “green building” movement. The University is committed to increasing sustainability in its new construction. Therefore, the approach will be to increase both energy usage and demand in proportion to campus building expansion while adding the usage and demand of the Cyclotron separately.

Finally, the latest Campus Master Plan Update report states, “The campus has historically added an average of approximately 200,000 gsf every fiscal year.” Campus building growth has been reduced during the past five years, however, many of the replacement buildings have been high energy research buildings, such as FRIB, PSSB Addition, Life Science Addition, and Wells Hall Addition, replacing low energy structures. Therefore, this analysis will focus on the 200,000 gsf instead of 100,000 gsf per fiscal year, though both sets of values are graphed.

The following tables and graphs show the projection of campus building expansion as recorded from FY 04-05 through FY 08-09 followed by growth at the rate of 200,000 gross square feet per fiscal year, and proportional expansion of steam and electricity demands and usage

Fiscal Year	Campus Utility	Electricity Peak Demand	Electricity Delivered
	sq ft	MW	MW hrs/yr
94-95	17,396,120	40.14	222,582
95-96	17,385,980	40.99	222,753
96-97	17,375,839	41.96	221,264
97-98	17,856,267	44.28	235,260
98-99	18,336,694	46.23	233,190
99-00	18,378,524	47.07	231,207
00-01	18,420,354	46.92	231,098
01-02	18,636,726	48.32	232,459
02-03	18,853,098	49.92	245,427
03-04	19,079,808	50.79	244,378
04-05	19,306,518	48.72	245,181
05-06	19,365,138	48.16	252,729
06-07	19,564,230	51.42	268,468
07-08	19,763,321	52.94	273,265
08-09	19,801,735	50.39	274,420
09-10	19,997,178	50.89	277,128
10-11	20,197,178	51.40	279,900
11-12	20,397,178	51.91	282,672
12-13	20,597,178	52.42	285,443
13-14	20,797,178	53.93	294,347
14-15	20,997,178	54.43	297,119
15-16	21,197,178	58.94	324,418
16-17	21,397,178	65.20	362,449
17-18	21,597,178	71.46	400,480
18-19	21,797,178	71.97	403,251
19-20	21,997,178	72.48	406,023
20-21	22,197,178	72.99	408,795
21-22	22,397,178	73.50	411,566
22-23	22,597,178	74.01	414,338
23-24	22,797,178	74.51	417,110
24-25	22,997,178	75.02	419,881
25-26	23,197,178	75.53	422,653
26-27	23,397,178	76.04	425,425
27-28	23,597,178	76.55	428,196
28-29	23,797,178	77.06	430,968
29-30	23,997,178	77.57	433,740

Table 2-5. Projected Campus Growth with Electricity Demand & Consumption

Fiscal Year	Campus Utility	Campus Steam Peak Demand	Steam Delivered to Campus
	sq ft	lb/hr	1000 lb/yr
94-95	16,120,406	510,000	1,996,837
95-96	16,110,098	596,000	2,190,270
96-97	16,099,789	565,000	2,336,253
97-98	16,495,499	535,000	2,409,522
98-99	16,891,208	602,000	2,566,532
99-00	16,932,858	602,000	2,448,072
00-01	16,974,508	640,000	2,516,930
01-02	17,188,145	526,000	2,537,685
02-03	17,401,781	646,000	2,803,598
03-04	17,434,297	585,000	2,608,932
04-05	17,466,812	638,000	2,747,212
05-06	17,525,432	576,530	2,890,812
06-07	17,501,955	537,000	2,799,349
07-08	17,478,478	627,380	2,780,577
08-09	17,514,740	627,160	2,730,807
09-10	17,678,632	633,029	2,756,361
10-11	17,878,632	640,190	2,787,544
11-12	18,078,632	647,352	2,818,727
12-13	18,278,632	654,513	2,849,909
13-14	18,478,632	661,675	2,881,092
14-15	18,678,632	668,836	2,912,275
15-16	18,878,632	675,998	2,943,458
16-17	19,078,632	683,159	2,974,641
17-18	19,278,632	690,321	3,005,824
18-19	19,478,632	697,482	3,037,007
19-20	19,678,632	704,644	3,068,190
20-21	19,878,632	711,805	3,099,373
21-22	20,078,632	718,967	3,130,556
22-23	20,278,632	726,128	3,161,739
23-24	20,478,632	733,290	3,192,922
24-25	20,678,632	740,451	3,224,105
25-26	20,878,632	747,613	3,255,288
26-27	21,078,632	754,774	3,286,471
27-28	21,278,632	761,936	3,317,654
28-29	21,478,632	769,097	3,348,837
29-30	21,678,632	776,259	3,380,020

Table 2-6. Projected Campus Growth with Steam Demand & Consumption

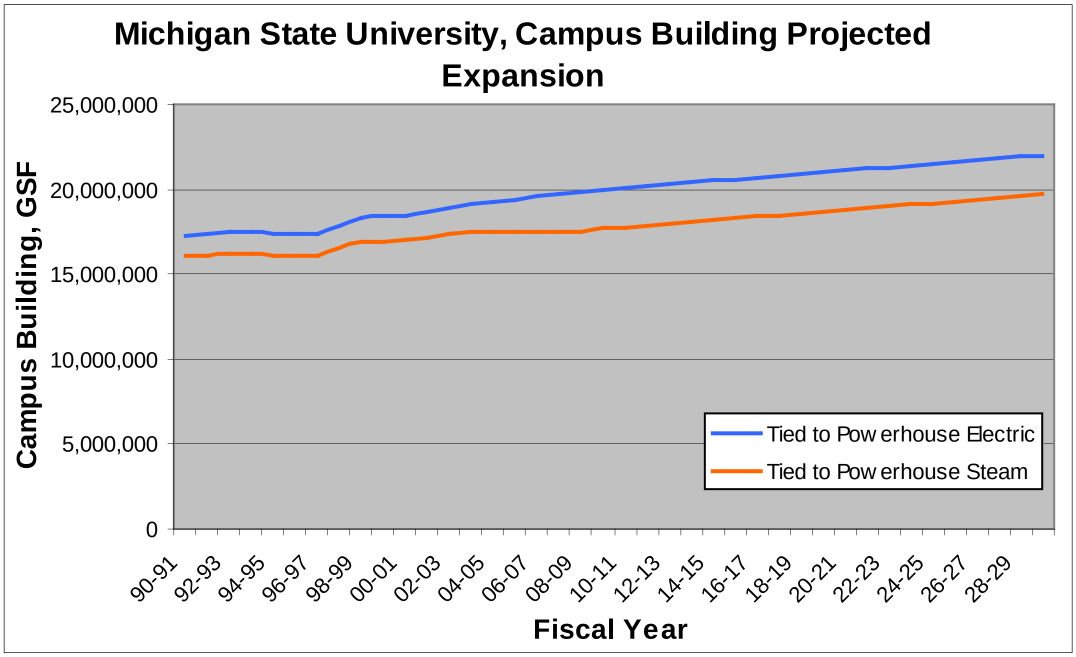


Figure 2-1. Campus Building Expansion

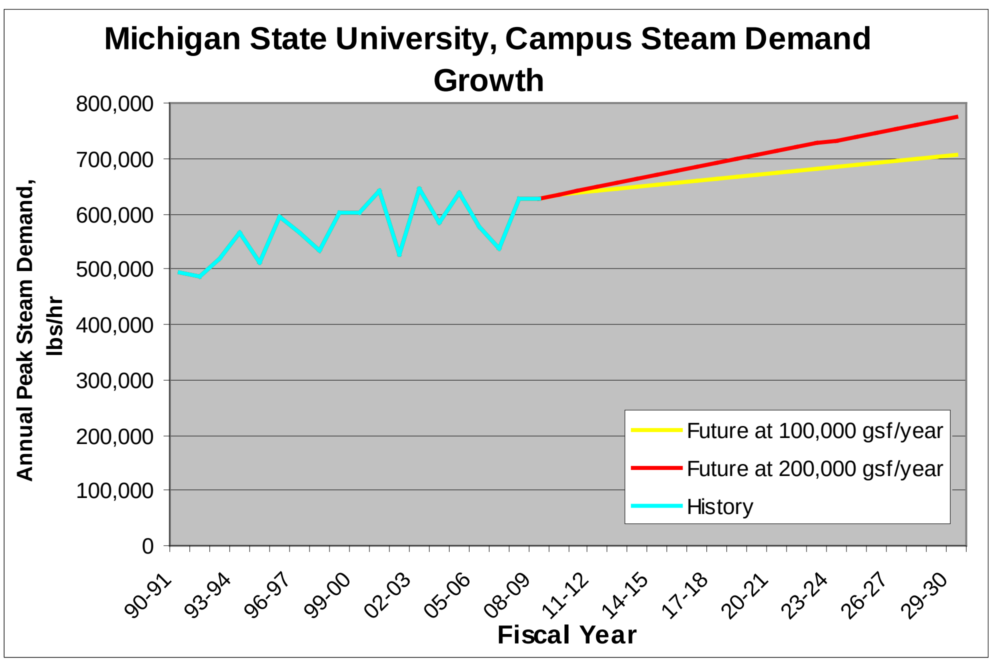


Figure 2-2. Campus Steam Demand Projection

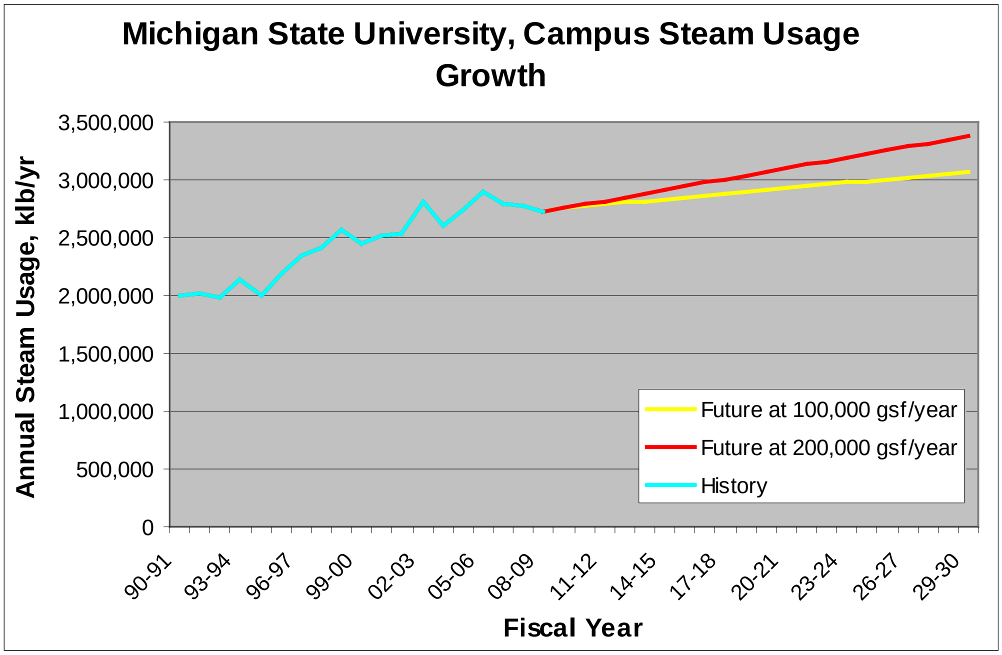


Figure 2-3. Campus Steam Usage Projection

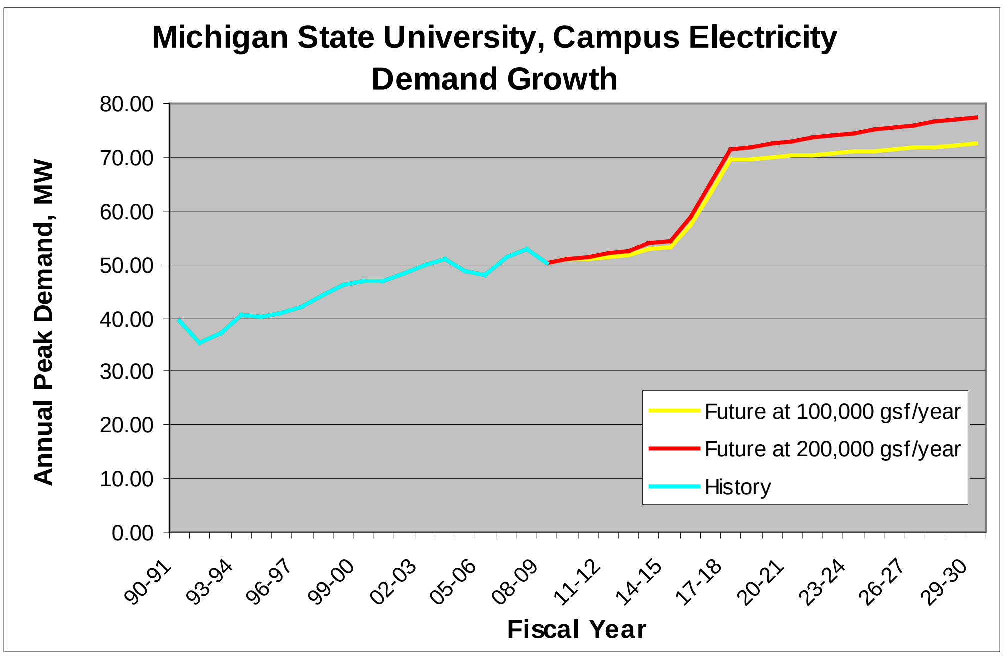


Figure 2-4. Campus Electricity Demand Projection

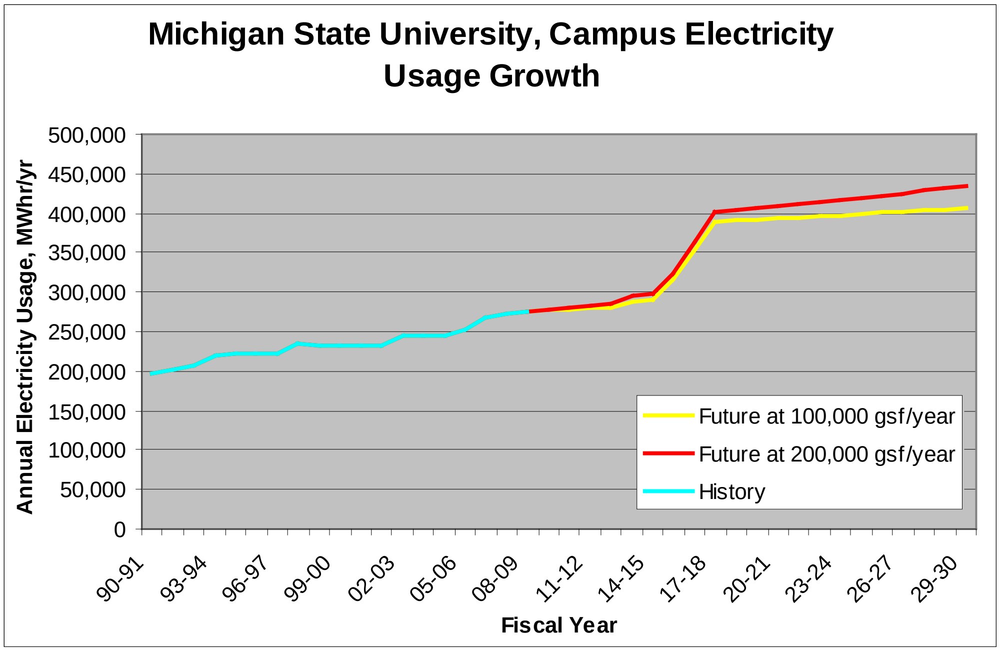


Figure 2-5. Campus Electricity Usage Projection

Given this framework of future energy demands and consumption, the next section outlines the capacities of the existing power plant and the issues surrounding it. It will be shown that the existing power plant has sufficient firm capacity to serve the campus thermal and electrical energy needs for the foreseeable future.

2.2 Summary of Existing Steam and Power Generation

The Michigan State University energy production and distribution system is based on a central steam and electric cogeneration plant with district steam underground distribution and medium voltage underground electric supply with two parallel feeders.

Cogeneration allows for greater system process efficiency and district heating avoids the need for individual boilers at each campus building. The central steam and electric cogeneration plant is the T. B. Simon Power Plant, and it is the only current source of heat for more than 19,000,000 square feet of campus building space.

The University's electric and steam supply relies on fifty year old coal fired steam boiler technology at the T. B. Simon for 65% of its energy capacity. The current plant has been well maintained and has sufficient capacity and is of a condition to support predicted University campus growth rates until 2023, however new regulatory pressures may require the addition of pollution control technologies which could end the useful life of some T. B. Simon Power Plant boilers before 2023. MSU needs to review and prepare for the next generation of energy supply.

T. B. Simon Power Plant Current Capacities

The T. B. Simon Power Plant is a system of independent steam generating units operating on a common 900 psig steam header, which can supply energy to 99 MW of cogeneration electric generation capacity.

Steam generating units, or boilers, are as follows:

- Boiler 1: 250,000 lb/hr, Wicks Boiler 1965
- Boiler 2: 250,000 lb/hr, Wicks Boiler 1965
- Boiler 3: 350,000 lb/hr, Erie City Boiler, 1973
- Boiler 4: 350,000 lb/hr, Tampella Boiler, 1993
- Boiler 6: 115,000 lb/hr, Nebraska Boiler, 2006

The total gross plant steam generating capacity totals 1,315,000 lb/hr. Boilers 1, 2 and 3 are pulverized coal fired boilers equipped with emission controls for particulate collection and NOx reduction. Pulverized coal firing is a highly efficient combustion technology, but requires post combustion processes for emission controls. Boiler 4 is a circulating fluid bed boiler (CFB), equipped with particulate collection, and SOx and NOx reduction. Boiler 6 is a heat recovery steam generator (HRSG) operating in a combined cycled configuration with natural gas turbine generator #6 which uses low NOx burner control.

Turbine generators are as follows:

- Steam Turbine 1: 12.5 MW
- Steam Turbine 2: 12.5 MW
- Steam Turbine 3: 15.0 MW off season gross, 9.0 MW summer peak demand gross
- Steam Turbine 4: 21.0 MW
- Steam Turbine 5: 24.0 MW
- Combustion Turbine 6: 14.0 MW

The total gross plant electric power generating capacity totals 99 MW. The Simon Plant electric capacity is backed up with a 21 megawatt interconnection with the local utility resulting in a gross total of 120 MW capacity. During the summer and winter periods of extreme temperatures, a portion of the steam allocated to Steam Turbine 3 is sent to the campus underground steam distribution system for the purpose of heating the buildings during the winter and energizing steam campus building absorption chillers during the summer. The result of delivering the peak campus steam during these periods is that Steam Turbine 3 will generate only 9.0 MW of power. This is most critical during the summer when steam demands for absorption chiller cooling peak and campus electric demands for electric air conditioning also peak. Therefore, the summer gross total power from steam turbine generators and the local utility interconnection is 114 MW capacity.

The utility interconnection provides reliability to the university in the form of emergency electricity supply.

The common underground steam distribution header at 90 psig from the central power plant allows for various plug in technologies for added or replacement steam generation.

This system of a central cogeneration plant simultaneously supplying electricity and district steam provides superior energy efficiency therefore offering a fundamental economic and reliability advantage to the University over electric only fossil fueled power generating plants. This is because the district steam system provides a use for the waste heat produced by any fossil fueled plants that is not available to off-site electricity generating stations. The following discussion reviews the issues and options available to maintain this advantage at the T. B. Simon Plant.

Energy Planning Metrics

When planning energy supply systems, the amount of instantaneous energy required by the consumers must be considered. This instant energy requirement is referred to as demand. Peak demand will determine the capacity of the system that is required. MSU's current historical peak demands are 61.4 megawatts of electricity and 663,000 pounds of steam per hour. Peak demand for electrical supply normally occurs in the summer for cooling, and peak demand for steam occurs in the winter for space heating.

The T. B. Simon Power Plant currently has a gross energy production capacity of 93 megawatts of electricity during periods of peak steam demand and 1,315,000 pounds of steam per hour. Adding in the local utility supply capacity of 21 megawatts yields a total gross electric supply capacity of 114 megawatts. The reliability measure for this equipment is the firm capacity. Firm capacity is defined as the capacity to provide generation with the largest unit in the fleet out of service. The University's electrical firm capacity is therefore 114 MW gross total – 24 MW from largest unit = 90 megawatts. There is a plan to add capacity to the transformers and interconnections to the local utility to serve the large future loads expected from the FRIB. With the plan for a new interconnection to the public utility, the plant will have enough electrical generating capacity to meet the campus demand for the foreseeable future.

As calculated for firm electricity capacity, steam generation firm capacity is calculated at 1,315,000 pounds of steam per hour gross total – 350,000 pounds of steam per hour from largest unit = 965,000 pounds of steam per hour. Steam generation at the T.B. Simon Power Plant is dispatched to meet the demands of both steam and electricity from the campus buildings. Often times, producing enough electricity to satisfy building demands requires the production of more steam than is demanded from the buildings for steam. This excess steam demand for electricity generation is shown in the table and graph below, and it is based on building area served by the electric utility. The table and graph show historic total steam production for the past 19 years, and then projected into the future to serve campus loads added at the campus average build out rates of 100,000 and 200,000 square feet per year.

Fiscal Year	Campus Utility, based on 100,000 sf/year growth	Powerhouse Peak Steam Production Rate	Campus Utility, based on 200,000 sf/year growth	Powerhouse Peak Steam Production Rate
	sq ft	lb/hr	sq ft	lb/hr
94-95	17,396,120	705,000	17,396,120	705,000
95-96	17,385,980	760,000	17,385,980	760,000
96-97	17,375,839	792,000	17,375,839	792,000
97-98	17,856,267	812,000	17,856,267	812,000
98-99	18,336,694	841,000	18,336,694	841,000
99-00	18,378,524	835,000	18,378,524	835,000
00-01	18,420,354	819,000	18,420,354	819,000
01-02	18,636,726	777,000	18,636,726	777,000
02-03	18,853,098	839,000	18,853,098	839,000
03-04	19,079,808	841,000	19,079,808	841,000
04-05	19,306,518	811,000	19,306,518	811,000
05-06	19,365,138	826,900	19,365,138	826,900
06-07	19,564,230	853,650	19,564,230	853,650
07-08	19,763,321	880,640	19,763,321	880,640
08-09	19,801,735	887,600	19,801,735	887,600
09-10	19,997,178	879,431	19,997,178	879,431
10-11	20,097,178	883,829	20,197,178	888,226
11-12	20,197,178	888,226	20,397,178	897,022
12-13	20,297,178	892,624	20,597,178	905,817
13-14	20,397,178	897,022	20,797,178	914,613
14-15	20,497,178	901,420	20,997,178	923,409
15-16	20,597,178	905,817	21,197,178	932,204
16-17	20,697,178	910,215	21,397,178	941,000
17-18	20,797,178	914,613	21,597,178	949,795
18-19	20,897,178	919,011	21,797,178	958,591
19-20	20,997,178	923,409	21,997,178	967,386
20-21	21,097,178	927,806	22,197,178	976,182
21-22	21,197,178	932,204	22,397,178	984,977
22-23	21,297,178	936,602	22,597,178	993,773
23-24	21,397,178	941,000	22,797,178	1,002,568
24-25	21,497,178	945,397	22,997,178	1,011,364
25-26	21,597,178	949,795	23,197,178	1,020,160
26-27	21,697,178	954,193	23,397,178	1,028,955
27-28	21,797,178	958,591	23,597,178	1,037,751
28-29	21,897,178	962,988	23,797,178	1,046,546
29-30	21,997,178	967,386	23,997,178	1,055,342

Table 2-7. Projected Powerhouse Steam Production Rate

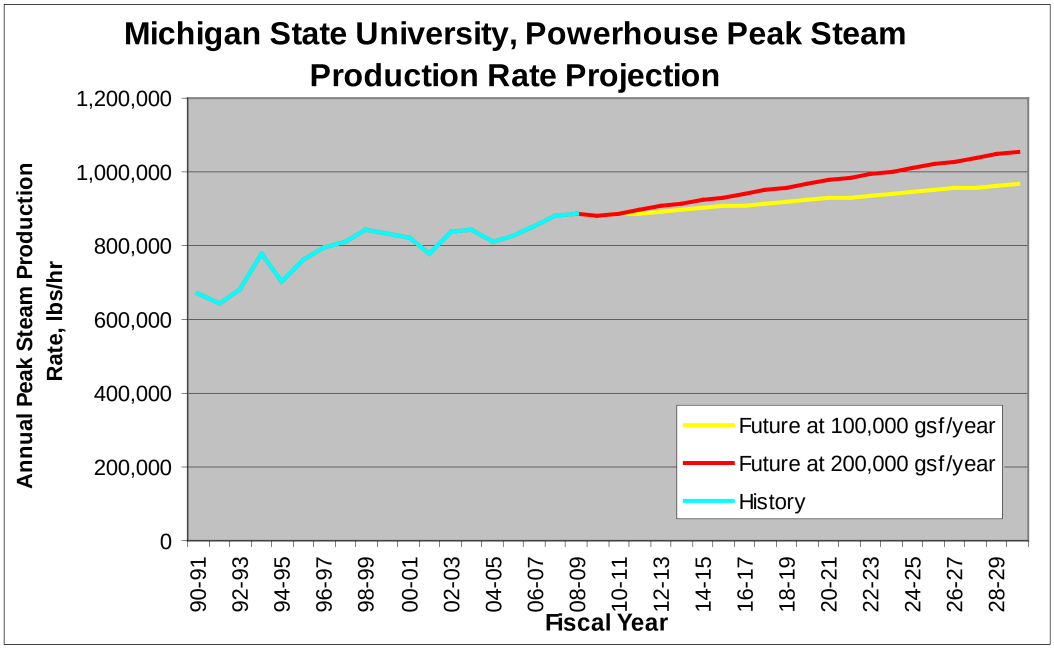


Figure 2-6. Projected Powerhouse Steam Production Rate

The capacity gap between maximum peak demand and firm capacity is the tool to predict when demand growth will require capacity changes. MSU historical growth of 2 million square feet per decade has contributed to an increase of the average annual energy consumption growth rate of 2%. The growth in demand for electricity and steam has been less than the growth of consumption, suggesting reductions of demand peaks. Projection of historical growth indicates that demand for steam to serve both campus thermal demands and powerhouse demands for electricity production will not exceed the 965,000 lbs/hr firm capacity with existing systems until 2028 at a campus growth rate of 100,000 sq ft average per year and 2019 at a campus growth rate of 200,000 sq ft average per year. The need for new electric generating capacity will determine capital cost requirements for system additions, and this capital spending may be directed to adding conventional steam power capacity or alternative technology electric generating capacity at the time of need. If alternative electric generating technologies are elected, the need for additional steam generating capacity may be deferred.

Regulatory Change Towards Clean Coal

Historically, clean coal technologies were considered as those emission control technologies that typically constituted Best Available Control Technology (BACT) which provided high reduction in post combustion emissions of particulate matter (PM), sulfur oxides (SO_x), nitrogen oxides (NO_x), acid gases, and hazardous air pollutants (HAPS). Currently, BACT for either pulverized coal or circulating fluid bed boilers has been dry electrostatic precipitators or baghouses for PM control, post combustion selective catalytic reduction (SCR) for NO_x control, wet or dry flue gas desulfurization for additional SO_x and acid gas control. In the near future, Clean Coal Technology would bring in other forms of pre-combustion control such as chemically washing minerals and impurities from the coal, gasification, carbon capture and storage technologies to capture the carbon dioxide from the flue gas and dewatering lower rank coals (brown coals) to improve the calorific quality, and thus the efficiency of the conversion into electricity.

Currently, under New Source Review/Prevention of Significant Deterioration (PSD) regulations, BACT does not include technology for CO_2 reduction and sequestration for new sources. However, recently projects have been required to address alternative technologies (i.e. integrated gasification combined cycle) within the BACT analysis, and have been required to include “capture ready” design considerations. Site issues, future regulations, and boiler details will determine if add on pollution prevention controls for emission reduction to achieve BACT are feasible for new and/or existing units.

The following are current regulations that will impact units at Simon Plant.

Industrial Boiler Maximum Achievable Control Technology (MACT)

The originally promulgated Industrial Boiler MACT also commonly referred to as the Boiler MACT, was vacated by the D.C. Circuit Court in 2007. The U.S. EPA is currently developing a revised rule to meet the court mandate. On April 29, 2010, the U.S. EPA released the pre-publication version of the draft Boiler MACT rule for major sources along with three other proposed rules. These are the area source MACT rule that is applicable to minor sources of hazardous air pollutants (HAPs), definition rules for non-hazardous solid waste and the commercial and industrial solid waste incinerator (CISWI) rules.

Boiler MACT regulates emissions of certain HAPs and/or their surrogates from new and existing boilers. As proposed, the draft revised Boiler MACT rule will regulate mercury, hydrochloric acid (HCl), carbon monoxide, particulate and dioxin/furans from industrial boilers. Emission compliance is required on a continuing basis and at all times including periods of startup and shutdown. The proposed rules were published in the federal register mid-May 2010, which initiated a 45-day commenting period on the proposed rules. The USEPA is under court ordered mandate to finalize the Boiler MACT rule by December 16, 2010. Compliance for existing units such as the boilers at the T.B. Simon Power Plant, will need to be demonstrated within three years of the publication of the final rule. A one-year extension could be granted on a case-by-case basis for compliance projects that require the installation of back-end air quality control equipment.

The attached table shows a comparison of the emissions currently being achieved (based on the 2006 Boiler MACT Compliance tests) as compared against the proposed Boiler MACT limits. As shown in the table, HCl control will be the main issue for all boilers, whereas, Hg could be an issue for Unit 3. Although Unit 1 is showing PM emissions higher than typical, Black & Veatch believes that a potential bag leak during the 2006 stack tests could have resulted in higher than typical PM.

Emissions of CO and Dioxins/Furans are still unknown for all the boilers except for a single set of data obtained for Unit 1 during the Information Collection Request (ICR) testing in 2009. Further testing and trials will be required to evaluate if the boilers will be able to comply with the proposed CO and dioxins/furans emission limits.

The Boiler MACT as proposed, will also require MSU to install CO and PM CEMS on all the four units. Additionally, a one time energy audit will be required as part of the initial compliance demonstration.

Proposed Boiler MACT Limits as Applicable to T.B. Simon Power Plant **Note: Boiler MACT Limits apply at all times**				
MSU T.B. Simon	**Unit 1**	**Unit 2**	**Unit 3**	**Unit 4**
PM Proposed MACT Limit (lb/MMBtu)	**0.02**	**0.02**	**0.02**	**0.02**
2006- PM (lb/MMBtu)	**0.049**	0.0105	0.0178	0.001
% Control Reqd.	**59.18**	0.00	0.00	0.00
HCl Proposed MACT Limit (lb/MMBtu)	**0.02**	**0.02**	**0.02**	**0.02**
2006- HCl (lb/MMBtu)	**0.136**	**0.139**	**0.118**	**0.082**
% Control Reqd.	**85.29**	**85.61**	**83.05**	**75.61**
Hg Proposed MACT Limit (lb/Trillion Btu)	**3**	**3**	**3**	**3**
2006 - Hg (lb/Trillion Btu)	1.99	1.01	**3.94**	0.169
% Control Reqd.	0	0	**23.86**	0
CO Proposed MACT Limit ppmvd @ 3% O_2	**90**	**90**	**90**	**30**
ICR -CO ppmvd @ 3% O_2	68.16			
% Control Reqd.	0			
Dioxins/Furans (Total TEQ - ng/dscm @ 7% O_2)	**0.004**	**0.004**	**0.004**	**0.002**
ICR D/F ng/dscm @7% O_2 (mass)	TBD			
ICR D/F ng/dscm @7% O_2 (TEQ)	TBD			
% Control Reqd.				
Heat Input (Mbtu/hr)	338	338	429	433
Boiler MACT for Major Sources applies to MSU. * Unit 1 PM appears to be the result of a broken bag **Red** numbers indicate the current emissions will not comply with the proposed MACT Proposed MACT emissions taken from the proposed Rule dated April 29, 2010				

Figure 2-7. Proposed Boiler MACT Emissions Limits

Sulfur Emissions

Boiler 3 has historical compliance pressures for its sulfur emission rates. This unit is not equipped with SO_x reduction controls; instead it is dependent on satisfactory performance by fuel suppliers in meeting the University specification for fuel for this unit. This Unit will be operating under a Michigan Department of Environmental Quality Consent Order until 2012.

The problematic compliance with the sulfur emission rates, combined with the fact that compliance with Boiler MACT can only be expected with a significant modification leads to the conclusion that Boiler 3 will likely be changed to a natural gas fired unit. The switch of Boiler 3 to natural gas will provide approximately 40,000 tons of CO_2 reduction, a 7% reduction. Furthermore, the emission limits for natural gas fired units will be significantly different than coal fired units and potentially provide a compliance pathway for Boiler 3. It remains to be seen if the conversion to gas firing will classify Boiler 3 as a new reconstructed gas boiler or an existing gas boiler. It is expected that this boiler will transition to natural gas firing by 2013.

CAIR

CAIR is the Clean Air Interstate Rule designed to reduce emissions of SO_x and NO_x helping states in the eastern United States meet and maintain the National Ambient Air Quality Standards (NAAQS) for ground-level ozone and fine particulate matter (PM2.5) pollution. This rule subjects MSU boilers to annual and summer NO_x emissions trading program. However, in response to a federal appeals court ruling, the EPA is developing a replacement rulemaking that they expect to finalize in 2011. In the meantime, the Phase I requirements of CAIR will continue to be in effect. Compliance can be achieved by either installing equipment to reduce emissions and/or acquiring allowances for the regulated emissions. No modifications to MSU units are expected as a result of this rule.

NSR

NSR is the New Source Review provisions of the Clean Air Act. Under these provisions modifications and repairs of existing boilers that result in increased emissions above thresholds established for each criteria pollutant will trigger a NSR review and potential BACT requirements under the PSD program. Life extension and system improvements can potentially trigger an NSR/PSD (prevention of significant deterioration) review. Environmental interests could make claims that Units 1, 2 and 3 (850,000 tons of plant steam capacity) should be subject to PSD review because the accumulated expenses for preventative maintenance have allowed life extension and created additional pollution potential.

Climate Change

In an effort to reduce manmade contributions to climate change, specifically global warming, greenhouse gas emissions from manmade processes are expected to be regulated. The primary greenhouse gas is carbon dioxide emitted from combustion processes where fossil fuels are used. Fossil fuel electrical power generating stations are prime targets for regulation. Federal reporting of greenhouse gases will be required for Calendar year 2010. MSU voluntarily joined Chicago Climate Exchange in 2006 and has a reported 2008 baseline of CO_2 emissions of 602,327 tons. It is expected that rules for reduction of greenhouse gas emissions will be in place no later than 2015. Current legislation being considered in Congress calls for overall reductions of 17-20% by 2020 and over 80% by 2050, through a cap-and-trade program that would begin in 2012. MSU can reach approximately 10% reduction in CO2 with the addition of alternative/renewable fuels. MSU units can reach a 50% reduction in CO2 by fuel switching all coal fired boilers to natural gas.

Summary Planning for the transition from current to future – near term

Continuing to monitor regulatory change—implement recommended minor modifications to Boilers 1 & 2 (2010-2012) - fuel switch for Boiler 3 to natural gas as a regulator escape valve (2013).

3.0 Issues and Trends

There are a number of trends in power generation, distribution, and consumption which may affect the T.B. Simon Power Plant and the University campus as a whole. The following is a list of the trends which should be considered in establishing an electric and thermal energy strategy.

Purchased electricity, available sources, costs, and anticipated trends
- traditional local suppliers: Lansing Board of Water and Light, Consumers Energy
- power grid enhancements and expanded supplier opportunities

Traditional fossil fuels, available sources, costs, and anticipated trends
- coal – current supplier
- natural gas – Consumers Energy
- petroleum – currently no capability to burn fuel oil at T.B. Simon Power Plant

Clean water, available sources, costs, and anticipated trends

Environmental issues including
- traditional air pollutants – PM10, SOx, NOx, HAPs
- carbon dioxide air emissions
- solid waste disposal
- waste water pre-treatment, treatment, and discharge

Current and anticipated government regulation especially regarding global climate change legislation and its impact on processes, especially power generation, which generate greenhouse gases as a byproduct

Reliability standards for power generation and increasing critical systems demands from
- research facilities, especially with animals
- communications, security, student records
- banking, accounting functions
- health care and hospitals

Sustainable and other energy technologies as alternatives to fossil fuel energy sources
- wind
- solar PV
- solar thermal
- biofuels: solids, liquids, and gases, sources on and off campus
- hydro power, static and dynamic
- tidal and wave
- geothermal
- small nuclear
- hydrogen cycle: electrolysis with fuel cells

ocean and lake vertical and horizontal temperature difference
osmotic pressure
biological
evaporation condensation
freeze thaw
distributed: engine generators, micro turbines, solar PV, fuel cells, small wind

Energy storage technologies becoming increasingly important as renewable energy technologies are implemented

flywheels
batteries
compressed air storage
hydrogen storage
pumped hydro storage
thermal energy storage

Plug-in Hybrid Electric Vehicles (PHEVs) and their anticipated impact on hourly demand as well as their ability to provide a source of stored power during an emergency

Current and expected government incentives

Energy conservation and recovery on the demand side

Lighting - curtailment based (occupancy sensors, etc.)
Lighting – retrofit bases (compact fluorescent, T12 to T8 lamp and ballast retrofit, LED,)
HVAC – retro-commissioning (eliminating simultaneous heat and cool)
HVAC – curtailment based (night set-backs, VAV retrofits, CO_2 demand ventilation)
HVAC – heat recovery, runaround loops, desiccant wheel dehumidification
HVAC – building envelope (windows, leakage, insulation upgrades, exterior shading)
HVAC – high efficiency chiller or DX retrofit
Chilled water – free cooling heat exchangers, delta-T improvement cold water reset
Hot water – hot water reset, condensing flue gas heat exchanger, solar thermal
Compressed Air – Leak detection, compressor retrofits
Energy Management – time of day, peak demand shut down, weather anticipation, customer access to real time costs and incentives to delay operations to lower cost periods

The scope of this report addresses Central Power Plant options in Section 4, Distributed Generation options in Section 5, Demand Side Management options in Section 6, followed by an evaluation process in Section 7.

4.0 Central Plant Options

This sections presents energy options applicable to the central heating/cooling/power generation plant approach. Given the existing T.B. Simon Power Plant, it is fitting to focus this section on energy options which can be integrated into the existing power plant or on the existing power plant site. This section also focuses on energy technologies which can be applied as central plant systems located on another site remote from the T.B. Simon Power Plant.

For many of the technologies, the following table is provided to summarize its characteristics.

Table of Technology Characteristics.

Capital Costs ($/kW)	
Applicability to the Lansing, Michigan region	
Applicability for a university campus	
Readiness	

Source: Put source here if applicable.

Notes:

[a] Use letters if there are three or more notes. Otherwise a star (*) or double star (**) should be used.
[b] Making these notes number themselves is more trouble than it is worth.
[c] The table number will automatically link to outlined number headings with style "Heading 1."
[d] All lines should be ½ pt.
[e] Table title is in style "Caption Table" which can be used to make auto list of tables.
[f] Don't use returns to make new lines in the table. Instead use "Insert Rows."

4.1 Natural Gas in Place of Coal

Simon Plant solid fuel boilers are equipped with capacity for full firing with natural gas. Natural gas combustion will provide 50 % reduction in carbon dioxide emissions when compared to coal firing. Natural gas will also provide significant reduction in SO_x and NO_x emissions. Long term forecasts for natural gas predict pricing at $6-8/mcf (Roger Smith, Black & Veatch, Coal Outlook Oct 26, 2009), 50-100% higher than historical coal prices. Use of natural gas as the plant primary fuel will significantly increase the cost of purchased fuel.

Table 4-1. Natural Gas Firing Characteristics.

Capital Costs ($/kW)	Unknown (potentially very low) [a]
Applicability to the Lansing, Michigan region	Consideration for PC Boilers 1 & 2.
Applicability for a university campus	Applicable
Readiness	Mature technology

Notes:
[a] Need to review natural gas supply agreements & system capacity

4.2 Biomass Co-firing

Use of renewable alternative fuels can provide reduction in green house gases by offsetting fossil fuel based combustion. An economical way to use alternative fuels in an existing fossil fuel power plant is to co-fire biomass with coal in the existing plant. Co-fired projects are usually implemented by retrofitting a biomass fuel feed system to an existing coal plant. Co-firing biomass in a coal plant generally has overall positive environmental effects. The clean biomass fuel typically reduces emissions of sulfur, net carbon dioxide, ash, and heavy metals, such as mercury. Overall emissions of NOx and carbon dioxide typically increase slightly, depending on the application and the ratio of co-firing. Compared to other renewable resources, biomass co-firing directly offsets coal use, resulting in a net-overall reduction of carbon dioxide emissions. Identifying the available biomass resources is a key early step in using this fuel, which may have economic benefits over coal as well.

Utility experience with biomass co-firing in the United States has primarily come from demonstration projects funded by the U.S. Department of Energy (DOE). These demonstration projects have been limited to the co-firing of biomass with coal in pulverized coal and cyclone boilers. More recently, co-firing test burns have been conducted by utilities such as Alliant Energy (at Ottumwa Generating Station), Ontario Power Generation (at Nanticoke Generating Station), and Southern Company (at Plant Gadsden). Currently, Kansas City Power & Light is testing the co-firing of coal and pelletized biomass at Sibley Generating Station. While several utilities are currently investigating co-firing options, Black & Veatch is unaware of any domestic utility-owned generating stations that have installed and are operating permanent co-firing systems. Domestic biomass firing is more established in stand-alone industrial boilers, especially in the pulp and paper industry in boiler that have been designed to utilize bark, as a by-product of their processes. There are other smaller non-industrial applications which have made the switch to biomass. The University of Iowa is presently burning oat hulls on a consistent basis.

Biomass utilization in Europe is widespread. Nearly every existing coal fired unit in the United Kingdom as adopted biomass co-firing, including PC units through various means of feed, including co-milling in the excising coal mills at ratios of 1-2 percent, or through dedicated bypass milling in ratios of approximately 10 percent or more with pelletized fuels. Studies have shown that co-milling of wood chips of 10mm top-size or less is achievable in existing PC units with minimal impacts, although there is a recognized significant potential for fouling the NOx reduction catalyst depending on the co-firing ratio. In addition co-fired ash may not be saleable because ASTM standards to not apply to ash produced from biomass. Co-fired ash also has the potential to increase fouling and slagging within the boiler, as well has affect ash particle size, depending on the biomass fuel type. Therefore, co-firing biomass has the potential to raise NOx emissions levels, and so SNCR retrofits are may be needed to control NOx on units with high co-firing ratios.

Industry experience in fuel switching up to 100% biomass in existing PC units is limited, but increasing in interest rapidly especially in Ontario Canada, where coal use is slated to be eliminated by 2013 by law. The replacement of coal with wood pellets in existing PC units (such as Boilers 1 and 2) can be expected to result in a significant derate (40% to 50%) and requiring the need for additional capacity in terms of additions to mills, bunkers, and perhaps boiler heat exchange surface area, combustion air fans, or additional boilers depending on the steam capacity target. Much of this derate is related to the reduced energy density of biomass, and the ability of existing fuel handling systems to transport the greater volumes of biomass needed to achieve the rated heat input. The use of wood and switchgrass pellets with <3mm top size constituent dust enables higher heat inputs on biomass using existing equipment because their low moisture content and high energy density relative to other forms of biomass like wood chips. The small particle size facilitates breakdown and transport using existing pulverizer systems. Special provisions for storage of wood pellets, which possess some hazards related to dust, off-gas production and self-heating at high moisture levels. The use of wood pellets is not expected to produce savings due to the generally high cost for the pellets, which can be equivalent to the cost for natural gas on a $/MMBTU basis. Because of this, the ability to utilize biomass in a more raw form, such as chips or cubes suitable for combustion in stoker or fluidized bed is generally preferred and such opportunities should be explored before resorting to pelletized fuels until their market cost is reduced.

MSU has an opportunity to burn biomass in Boiler 4 in the form of wood chips and other available forms because the CFB technology can be used to burn a variety of fuels. As such, Boiler 4 is a significant existing asset that may be readily converted to burn biomass, with some modifications. It may be possible to convert Boiler 4 to burn higher ratios of biomass than the 30% presently envisioned. Studying unit impacts and the available fuel supply should enable MSU to identify and evaluate conversion costs for each unit depending on their desired biomass ratio. Another benefit to using chips is that unlike pellets, wood chips do not need to be stored indoors, avoiding the need for covered storage facilities, which can be very significant considering the large volume of storage needed. Wood chips have an energy density that is approximately 1/10th that of coal. In general terms, 1 cubic foot of coal contains approximately 1 million Btu, whereas approximately 10 cubic feet of wood chips contains the same 1 million Btu.

Limited use (up to 10%) of alternative fuels while co-firing with coal can be accomplished in the T. B. Simon Plant Unit 4 with no significant capital changes. Co-firing of 2% via co-milling on PC units is an alternative, that may require some conditioning of the wood chips (grinding to size adequate for co-milling), or using dedicated mills, perhaps up to 10% on a heat input basis. This ratio on Boiler 4 would offset 8,000 tons of CO_2, or 1.3%. More extensive combustion, up to 30% or greater, is limited by the details of the material handling system and boiler design and will likely require capital improvements. Achieving 30% reduction would offset 24,000 tons of CO_2, a 4% reduction at the plant overall. Limited alternative fuel can be obtained at coal cost equivalent pricing, and this consists mostly of wood chips. Use of such fuel additives would have minimal impact on the operational budget.

T. B. Simon to Continue to pursue use of Biomass Fuels. (2009-2012)

The T.B. Simon Plant is currently permitted to burn switch grass and urban waste wood in the Unit 4 boiler. Actual burning of wood began in September 2009. It is predicted the MSU campus can provide 6,000 yd^3, or 1500 tons of chipped wood for T. B. Simon Plant use (Wood Staging Area Concept Design Project Bio Fuel Production Facility at MSU, School of Planning, Design and Construction report No. 08-01). This would offset approximately 750 tons of coal and approximately 1680 tons of CO_2 or 0.03 % of the 2008 baseline. The University must engage in the wood market if additional reductions are to be gained with wood firing.

The T. B. Simon Plant has conducted a successful test burn of process bio fuel in its Boiler 4. A business plan was developed to build a process plant adjacent to the T. B. Simon Plant which could supply 30% of the fuel required for Boiler 4, creating an estimated 54,000 tons of CO_2 reduction. This plan revealed that based on current economics and regulations the process does not have a positive cash flow on the investment. The concepts related to this plant and or acquiring processed bio fuel from a local merchant plant will continue to be explored. Commercial availability is not likely before 2011.

One area of potential concern is that the proposed Boiler MACT rules for biomass boilers include much tighter air quality control limits than for coal, which could lead to compliance issues when changing fuels from coal to biomass. When co-firing, however, the extent of the compliance issue may depend on the level of co-firing envisioned and whether or not the boiler will be characterized as a biomass fired boiler or coal fired boiler. The following table shows the comparison of the current limits for existing units, which are still under review by the EPA. If these proposed rules are promulgated, compliance costs for back end controls on existing units that switch to biomass could potentially rise significantly in order to achieve the tighter emissions targets, by some estimates as much as $800/kW, depending on the control technology needed.

Subcategory	PM	HCl	Hg	CO (ppm @3% O_2)	D/F (TEQ)(ng/dscm)
Coal Stoker	0.02	0.02	0.000003	50	0.003
Coal Fluidized Bed	0.02	0.02	0.000003	30	0.002
Pulverized Coal	0.02	0.02	0.000003	90	0.004
Biomass Stoker	0.02	0.006	0.0000009	560	0.004
Biomass Fluidized Bed	0.02	0.006	0.0000009	250	0.02
Biomass Suspension Burner/Dutch Oven	0.02	0.006	0.0000009	1010	0.03
Biomass Fuel Cells	0.02	0.006	0.0000009	270	0.02
Liquid	0.004	0.0009	0.000004	1	0.002
Gas (Other Process Gases)	0.05	0.000003	0.0000002	1	0.009

Source: USEPA

Figure 4-1. Existing Unit Emissions Limits

Table 4-2. Biomass Co-firing Technology Characteristics.

Capital Costs ($/kW)	600 [a] to 1400 [b]
Applicability to the Lansing, Michigan region	Consideration for CFB Boiler 4, or for PC Boilers 1 & 2.
Applicability for a university campus	Potential application[c]
Readiness	new but full scale installed technology with short operating history

Notes:
- [a] Indicative for biomass materials handling / feed equipment only.
- [b] Includes potential of $800/kW (indicative) for AQC compliance cost related to Boiler MACT
- [c] Material handling and Truck traffic considerations, as well as technical issues.

4.3 Energy Crops

There have been recent advances in technology that advance agricultural yields for native species. One such process has been developed by PetroAlgae.

Source: PetroAlgae http://www.petroalgae.com/technology.php

Figure 4-2. Energy Crops.

Special Applicability to MSU: PetroAlgae - This produces two product streams: high – protein solids suitable for animal feedstock, and high – carbohydrate solids that are suitable for combustion in a boiler, or with further refinement into biodiesel. Depending on climate suitability, and land availability, and micro-crop species (with emphasis on native species), significant volumes of biomass and protein may be obtained from a Petro-Algae facility. This is a new technology and should be evaluated against existing, locally obtainable bio-fuels.

For Michigan State University: The highest yielding energy crop process involves growing aquatic crops in an enhanced environment that produces rapid growth. Just like any other crop, it requires land, sunlight, and water. Such a facility located in a Northern climate is capable of producing 15 tons per year of fuel per acre, about half the yield available to a Southern climate. A 500 acre facility might produce 7500 tons of fuel annually in addition to perhaps 2000 tons per year of protein meal, a byproduct of the process. The total amount of this fuel needed to displace the 30% of coal burned in Unit 4 is approximately 130,000 tons, requiring nearly 9,000 acres. Clearly energy crops grown on the campus can only provide a small portion of the campus fuel needs, and would require a large portion of the available campus land area to do so.

Table 4-3. Energy Crop Characteristics.

Capital Costs ($/kW)	Unknown
Applicability to the Lansing, Michigan region	Crop yields expected to be low (50%) of normal due to reduced growing season.
Applicability for a university campus	Demonstration Project Only[a]
Readiness	Emerging Technology

Notes:
[a] The land needs for dedicated energy crop needed to provide significant fuel quantities is excessive for this climate, however the technology holds potential and should be screened again once the technology matures.

4.4 Biomass Gasification at Campus Setting

Biomass material can be gasified creating a fuel similar to natural gas, but with a much lower heating value. This fuel can be used to generate steam for thermal use or to generate electricity. Examples of this technology include the Oak Ridge National Laboratory (TN) steam plant. This plant is set to have a commercial operation date of 3Q 2011. It will use 242 tons/day of waste wood to generate 60,000 lbs/hr of 150 psig saturated steam to heating systems. At the University of South Carolina, a waste wood fueled gasification plant, similar in size to the ORNL plant has been operating since 4Q 2007. In Denmark, gasification has been used successfully to supply wood gas to fuel reciprocating engines in municipal hot water district energy applications. The engines produce electricity and hot water through jacket water and stack gas heat recovery. MSU has a district energy system that utilizes steam.

For Michigan State University: Gasifier equipment has yet to be installed in industrial and commercial scale power plants and is a retrofit alternative for pulverized coal boilers that may not be good candidates for either fluidized bed or stoker conversion. While feasible, gasification technology is generally regarded by industry as immature and expensive, and with greater risk for unsuccessful implementation over other available alternatives. Fluidized bed and stoker conversions are generally feasible, commercially available, and have a proven implementation history and are considered the technology of choice for facilities that wish to convert from coal to biomass. MSU has a circulating fluidized bed (CFB) boiler that is capable of burning biomass in solid form, and therefore avoids the need for gasification equipment. It should be noted that the direct injection of wood dust into commercial pulverized coal boilers as a means of adding biomass firing capability is a more recent technology than gasification, and yet has been widely implemented on existing PC units throughout the Netherlands and the United Kingdom, and is also of significant domestic interest lately as means to comply with state renewable portfolio standards. One potential benefit to gasification is the production of wood gas that is able to fuel internal combustion engines. If for some reason, campus electricity demand increases faster than steam demand, wood gas may be used for electricity generation independent of the campus steam load. This configuration is more prevalently used in demonstration projects than it is used commercially, and the selection of engines capable of utilizing wood gas is very limited.

Considering the many low cost choices that MSU has, to utilize biomass in their existing boilers which serve existing steam based distribution systems, gasification applications appear to offer relatively few additional benefits and potentially higher equipment costs.

Table 4-4. Biomass Gasification Technology Characteristics.

Capital Costs ($/kW)	Unknown
Applicability to the Lansing, Michigan region	Applicable
Applicability for a university campus	Potentially Suitable
Readiness	Emerging Technology[a]

Notes:
[a] Gasification projects using wood gas in indirect combustion processes (e.g. in a boiler) are proven and are being implemented in university settings. Considerations for gas clean up and tar removal needed to support direct firing processes (e.g. internal combustion engines) are much less proven, but could become commercially available, and proven in the near future.

4.5 Anaerobic Digestion

Biosolids from the treatment of municipal wastewater and animal manures from agricultural operations have been considered as potential sources of feedstock for anaerobic digestion projects. Anaerobic digestion (AD) is defined as the decomposition of biological wastes by micro-organisms, usually under wet conditions, in the absence of air (specifically oxygen), to produce a gas comprising mostly methane and carbon dioxide. Anaerobic digesters have been used extensively for municipal and agricultural waste treatment for many years. Traditionally, the primary driver for anaerobic digestion projects has been waste reduction and stabilization rather than energy generation. Increasingly stringent agricultural manure and sewage treatment management regulations and increasing interest in renewable energy generation has led to heightened interest in the potential for AD technologies. MSU is presently implementing a small anaerobic digester as a research project under the direction of Dr. Steve Safferman.

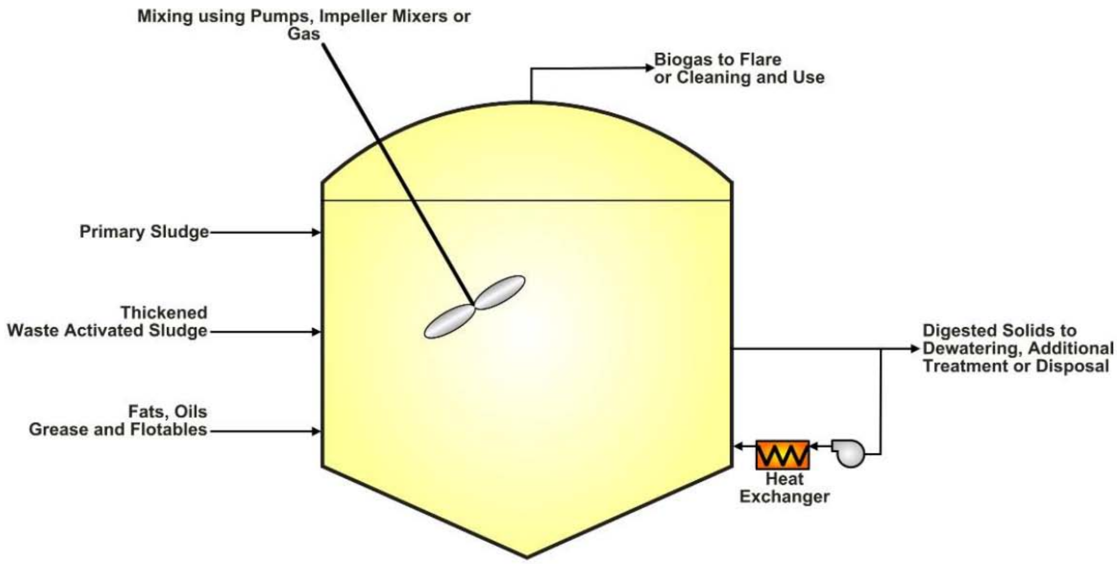


Figure 4-3. Schematic of a Single Vessel Anaerobic Digester.

In December 2006, a report issued jointly by the U.S. EPA and the Combined Heat and Power Partnership estimated that 220 MW of generation is produced through the anaerobic digestion of municipal biosolids at 76 facilities across the U.S. The U.S. EPA AgStar program tracks farm-based digestion projects across the U.S. Based on the most recent report issued in December 2008, there are currently 30 MW of electricity generated from more than 108 farm-based digesters. Another 25 MW of generating capacity is currently in the design and construction phase.

Biogas produced by AD facilities can be used in a variety of ways, including heating/steam generation, combined heat and power (CHP) production, gas pipeline injection, and vehicle fuel usage. Most commonly, biogas generated at digestion facilities is utilized onsite for process heat or CHP applications.

Another consideration when evaluating renewable energy potential from wastewater treatment facilities concerns enhancement opportunities for co-digestion. Co-digestion is the simultaneous digestion of two or more substrates that are mixed and processed as a homogenous solution. Fats, oils, greases (FOG) and food waste are examples of desirable, high-yield substrates that are available in densely populated areas.

For Michigan State University, anaerobic digestion of farm wastes and then capture of the biogas for use as a fuel locally could offer the potential to reduce purchased energy in the campus farms.

Table 4-5. Anaerobic Digestion Technology Characteristics.	
Capital Costs ($/kW)	8,000 to 16,000
Applicability to the Lansing, Michigan region	Potential applicability using wastewater, ag wastes and food wastes
Applicability for a university campus	Potential suitability
Readiness	mature technology with operational and maintenance history

4.6 Coal Gasification

The conversions of coal to a liquid fuel for transportation purposes and to a gas as a replacement for natural gas has been a known technology since the 1920's. In the more recent past, especially since the Arab oil embargo of the 1970's, coal gasification has been seen as the answer to finite natural gas resources. Coal gasification is the first stage of several processes to convert coal to liquid transportation fuels.

It has been found that coal gasification is also a method to make coal "clean coal" because it provides enhanced pollutant emission profiles. Coal gasification also offers a method to burn coal in combustion turbines which can take advantage of the higher thermal efficiencies for power generation available in a combined cycle process. For these reasons, integrated gasification combined cycle (IGCC) have been the focus of technology development and promise in the past two decades. There are two IGCC plants operating in the United States—one in Indiana and one in Florida—both constructed and initially operated with DOE support for clean coal technologies. The two operating plants are in the 250 to 275 MW capacity range. The high capital and operating costs of IGCC plants has limited other installations to demonstration projects.

Though coal gasification has been shown to provide cleaner emissions of traditional air pollutants, coal gasification does not offer currently desired CO_2 emission reduction simply because coal is a carbon fuel. Coal gasification would require additional carbon capture and sequestration technologies, which are also currently under development. IGCC plants offer a more promising way to capture the CO_2 than do conventional direct coal burning technologies, but costs of CO_2 capture are very high in terms of capital investment for the equipment as well as for the auxiliary plant loads to operate the systems.

Coal gasification has been installed on a limited commercial basis. Economic viability for this technology comes with higher energy prices.

4.7 Solar Photovoltaic

PV systems convert sunlight directly into electricity. The conversion of sunlight into electricity is known as the photovoltaic effect, and the materials and processes involved are very similar to semiconductors. The power produced depends on the material involved, the intensity of the solar radiation incident on the cell, and the cell temperature. Single or polycrystalline silicon cells are most widely used today. The figure below illustrates flat plate solar radiation intensity for the United States and how Michigan compares to the rest of the country.

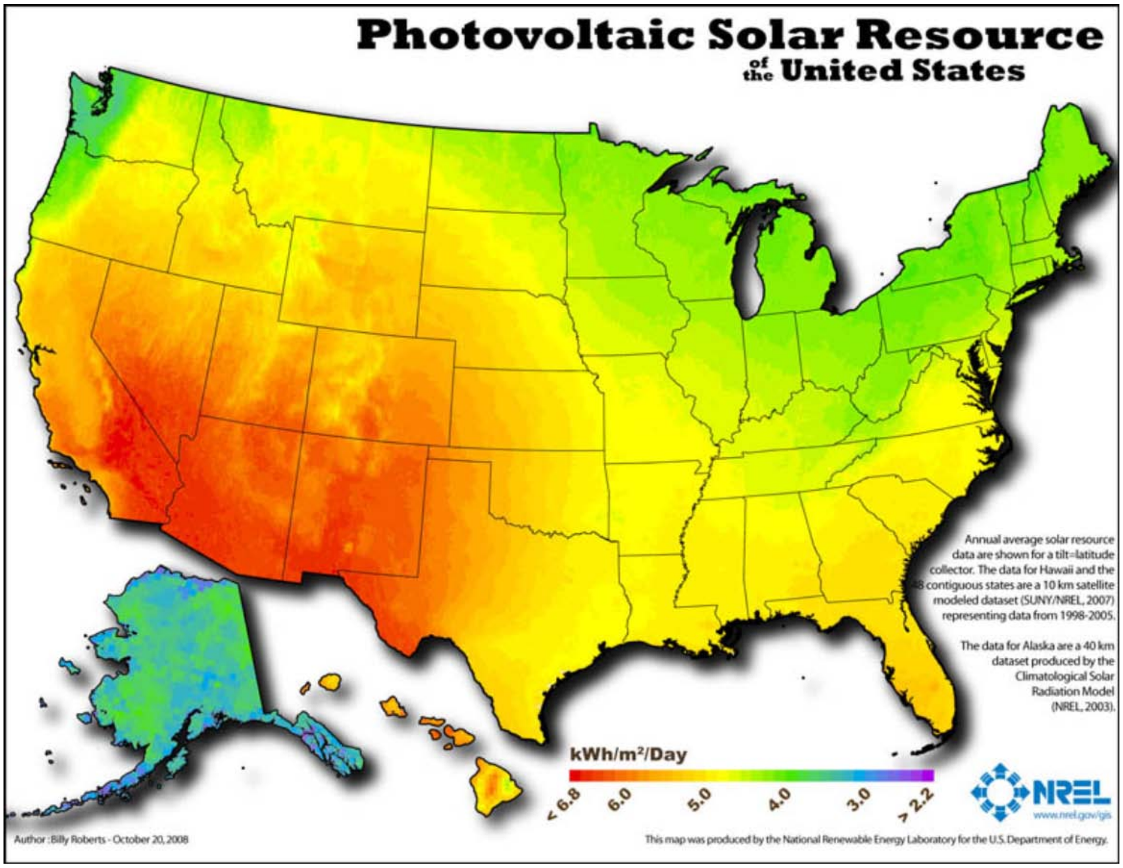


Figure 4-4. U.S. Solar Resource for Flat-Plate Photovoltaics

Single crystal cells are manufactured by growing single crystal ingots, which are sliced into thin cell-sized wafers. The cost of the crystalline material is significant. The production of polycrystalline cells, which are made from cast material rather than grown crystals, can cut material costs with some reduction in cell efficiency. Thin film modules, which are significantly less expensive but not as efficient, are also being used for large scale solar applications.

A PV system has two critical components: solar modules and inverters. The other important components include mounting system and hardware, disconnect switches, meters, and monitoring equipment. Solar modules convert sunlight directly into electricity, and the inverter converts the direct current (dc) electricity from the modules into alternating current (ac) electricity used by the electric grid.

Traditional wisdom in the solar industry has been that solar photovoltaic (PV) systems are appropriate for small distributed applications. More recently, PV systems are being constructed in larger sizes up to and including utility-scale applications. PV systems as large as 60 MW have been installed in Europe. A 15 MW system was installed at Nellis Air Force Base in Nevada, the 10 MW El Dorado Solar system was installed near Boulder City, Nevada, and an 8.2 MW system was installed near Alamosa, Colorado. Worldwide, there are more than fifty PV installations over 10 MW and more than 600 systems that are 1 MW or greater in capacity. Furthermore, hundreds of megawatts of central station PV systems are being bid in the U.S. in response to utility requests for proposals. Nearly all of this capacity has been flat plate PV rather than concentrating PV.

Figure 4-5. Photovoltaic Installation at Nellis Air Force Base

For Michigan State University, PV system designs would need to be based on the estimation of useful day lighting. Physical Plant's Energy and Environmental Engineer estimates, based on Michigan geographic location, 400 to 500 acres of panels would be required to support the existing 61.4 MW of campus electric demand. The total existing roof space is approximately 8 million sq feet (source Physical Plant Maintenance Services roofing Dept). Since much of the roof space is currently used for other process functions the potential usable acreage would be significantly less, perhaps 30% of the total or 55 acres. So PV maximum potential using existing roof area is 11-13 % of the demand. Even though campus building roof PV panels would not be able to serve all of the campus electricity demands, utilizing the roofs could supplement the demands building-by-building as distributed on-site generation. See the section 6 Distributed Generation for siting PV systems at campus buildings.

Construction of a solar farm of 500 acres of high density PV would be a central plant concept which utilizes the existing electrical distribution system and avoids extensive building renovation costs.

The demonstrated PV efficiency on the MSU campus using monocrystalline silicon solar cells in an anodized aluminum frame with tempered glass face is 10% (based on 30 kv at MSU Recycling). Since PV can only provide electricity during periods of sunlight, supplemental energy systems would be required for the balance of the electrical demand and the variability of supply using PV. Solutions which are heavily dependent on PV will require additional concepts to maintain building heating systems.

For planning purposes the supplemental system sizing would be based on the assumption of minimum PV output during peak demand periods.

Table 4-6. Photovoltaic Technology Characteristics.

Capital Costs ($/kW)	$4000 - $5000
Applicability to the Lansing, Michigan region	Adequate resource
Applicability for a university campus	Suitable
Readiness	mature technology with operational and maintenance history

Notes:
[a] Most of the U.S. has adequate or better resource for solar photovoltaics.

4.8 Solar Thermal Power Generation

In the early 1990's, the DOE and a group of California utilities built and operated a 10 MW solar thermal power plant which started with the generation of steam produced by direct concentrated sunlight. The project named Solar One was built in the Mojave Desert. As with solar PV, the power produced depends on the intensity of the incident solar radiation. Thermal systems concentrate the sun's energy by reflecting the incident solar radiation from mirrors of a large area onto a cell of a small area. The figure below illustrates concentrating solar radiation intensity for the United States and how Michigan compares to the rest of the country. In this case, direct sunlight is required to concentrate the heat. On cloudy days, concentrating mirrors are ineffective, rendering eastern regions of the Great Lakes and the northwest less suitable for concentrating solar thermal facilities. The figure clearly shows why the Mojave Desert was selected for the Solar One demonstration.

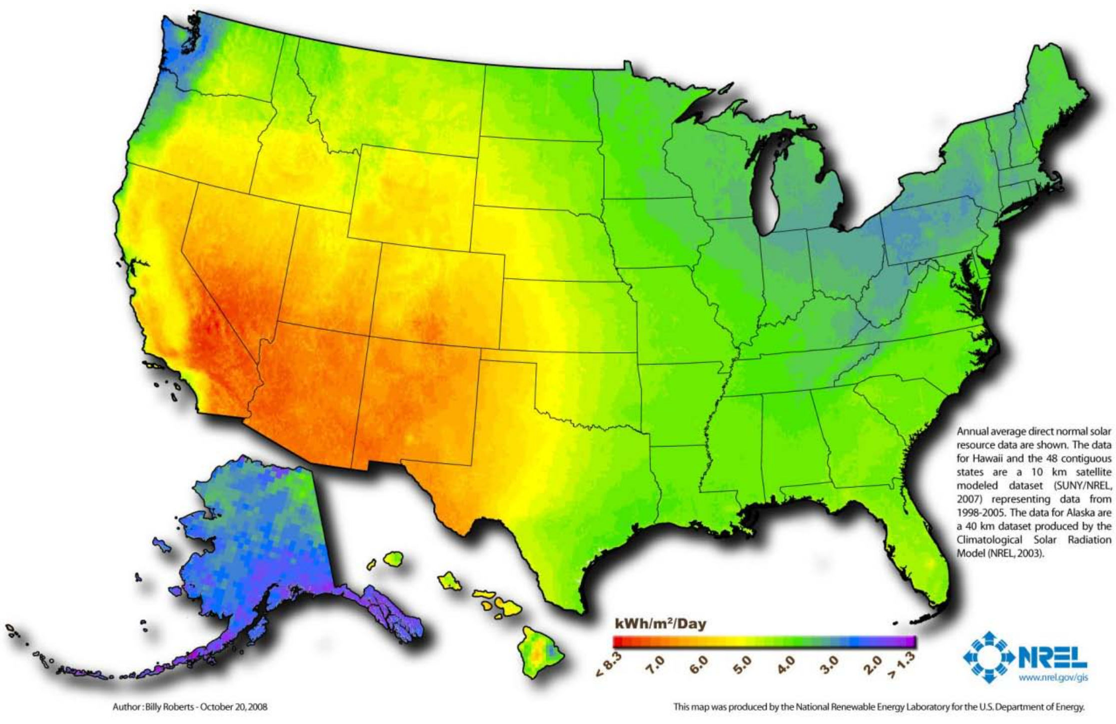


Figure 4-6. U.S. Solar Resource for Concentration Thermal Collectors

For the Solar One facility, the steam generator stood as a light receptor at the top of a tall tower with as array of more than one million square meters of mirrors focused on the receptor. The generating plant, occupying more than 126 acres of desert, was known as

Solar One, and it proved to be more of a learning experience than a reliable source of electricity. One of the most important lessons was that it is nearly impossible to control steam temperature when it is produced from an intermittent heat source, such as the sun, especially when clouds are present.

The solution to this problem was to use the sun to heat molten salt. By heating the salt—sodium and potassium nitrate which has a high specific heat—solar thermal energy can be stored for a period of time to provide a more even production output as clouds pass overhead and for a controlled period of time at the end of the day. Employing this technology provides the ability to produce steam at a constant temperature and flow by controlling the flow and temperature of the molten salt, therefore compensating for passing clouds and even providing a reserve of power for an hour or two at the end of the day. This improvement led to Solar Two—also a 10 MW plant which has formed the basis for the design of more commercially viable solar thermal generating plants.

Figure 4-7. Arial View: Solar Two, 10 MW Thermal Tower Plant with Mirrors

The molten salt is heated to more than 1000F in a heat exchanger receptor made of hundreds of small tubes. The molten salt is piped to another heat exchanger which produces steam in the same way as steam is produced in a coal or natural gas fired boiler. From here the steam is used to power a steam turbine generator and is then condensed, deaerated, and pumped back to the molten salt heat exchanger completing the Rankine cycle, again similar to the thermal cycle in the coal fired power plant.

A 200 MW plant in the American Southwest would use 17,000 heliostat flat glass mirrors arranged in a circular pattern around the tower. The heliostat moves the mirrors in all directions to direct the sun's rays onto the receptor as the sun tracks across the sky. Such a plant could have an installed capital cost of $4,000 to $5,000 per kW of capacity, or $800 million to $1 billion total.

Figure 4-8. Ground View of Solar Thermal Power Tower in Spain

Figure 4-9. Arial View: Solar Thermal Power Towers with Heliostat Mirrors

Another way to capture heat from the sun for producing steam in a Rankine cycle power plant is to use trough shaped mirrors in straight rows. The troughs focus the sun's rays onto a single pipe in the trough. The pipe heats molten salt as described above for the tower receptor. The pipes do not move, but the trough shaped mirrors move to keep the sun's rays concentrated onto the pipe throughout the day.

Figure 4-10. Arial View: Solar Thermal Power Trough Mirror Plant

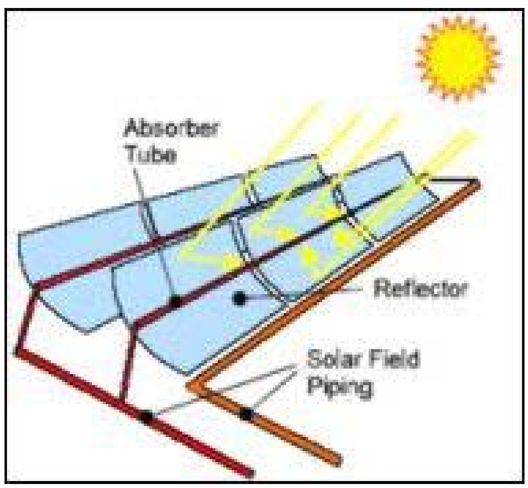


Figure 4-11. Solar Thermal Power Trough Mirror Diagram

A small scale solar thermal system for producing electricity is the modular Sterling engine-generator heated by a solar concentrating mirror all on a single platform. Producing no more than 150 kW, these may be suitable for distributed generation but may also be suitable for central plant on a modular basis. The next figure illustrates the current technology.

Figure 4-12. Solar Sterling Engine on a Parabolic Reflector Dish

Table 4-7. Solar Thermal Technology Characteristics.

Capital Costs ($/kW)	$4000 - $5000
Applicability to the Lansing, Michigan region	Poor location based on solar concentration [a]
Applicability for a university campus	Potentially suitable based on land availability
Readiness	mature technology with operational and maintenance history

Notes:
[a] Most of the U.S. is adequate or better resource for solar thermal availability, but concentrating system viability has only been found in the southwest.

4.9 Wind

Wind power systems convert the movement of air to power by means of a rotating turbine and a generator. Wind power has been among the fastest growing energy sources over the last decade, with around 30 percent annual growth in worldwide capacity over the last 5 years. The World Wind Energy Association states that cumulative worldwide wind capacity is now estimated to be more than 121,000 MW. Total installed wind capacity in the United States exceeded 35,000 MW as of December 2009. The US wind market has been driven by a combination of growing state mandates and the Production Tax Credit (PTC), which provides an economic incentive for wind power. The PTC has been renewed several times and is currently set to expire on December 31, 2012.

Typical utility-scale on-shore wind energy systems consist of multiple wind turbines that range in size from 1.5 MW to 3 MW produced by companies like Vestas, GE, and Siemens. The size range of off-shore wind turbines has grown to approach 10 MW produced by companies like Clipper, Windpower, Enercon, and REpower. Utility-scale wind energy system installations may total 5 MW to 300 MW. The use of single, smaller turbines is also common in the United States for powering schools, factories, water treatment plants, and other distributed loads. Community wind projects in the U.S. involve a cluster of turbines, sometimes as part of a larger utility-scale wind farm, to provide power for a town, a large campus or other facility.

Utility-scale wind turbines can be very large. The following figure comparing the Vestas V80 1.8 MW wind turbine to the Statue of Liberty and an Airbus A300.

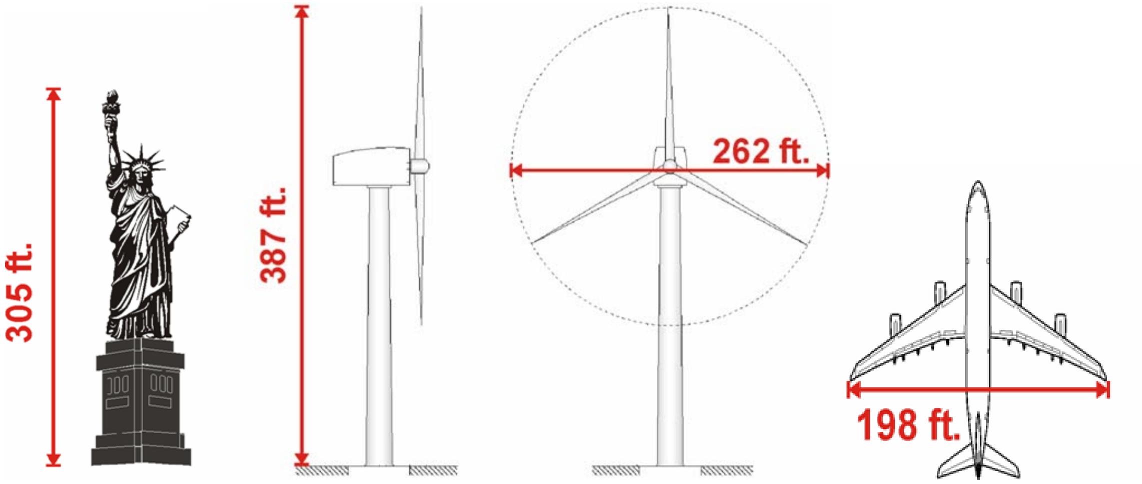


Figure 4-13. 1.8 MW Wind Turbine Size Illustration

Figure 4-14. 660 kW Kansas Wind Turbine Blade

Wind is an intermittent resource, with average capacity factors ranging from 25 to 40 percent. The capacity factor of an installation depends on the wind regime in the area and the energy capture characteristics of the wind turbine. Capacity factor directly affects economic performance; thus, reasonably strong wind sites are required for cost-effective installations. MSU conducted a year long wind study at 150 feet and 300 feet roughly, using anemometers on the radio tower. Professor Jeff Andreson, a climatologist conducted the study and found at this location we have less than 20 percent utilization. Since wind is intermittent, it cannot be relied upon as firm capacity for peak power demands. To provide a dependable resource, wind energy systems may be coupled with some type of energy storage to provide power when required, but this is not common and adds considerable expense to a system.

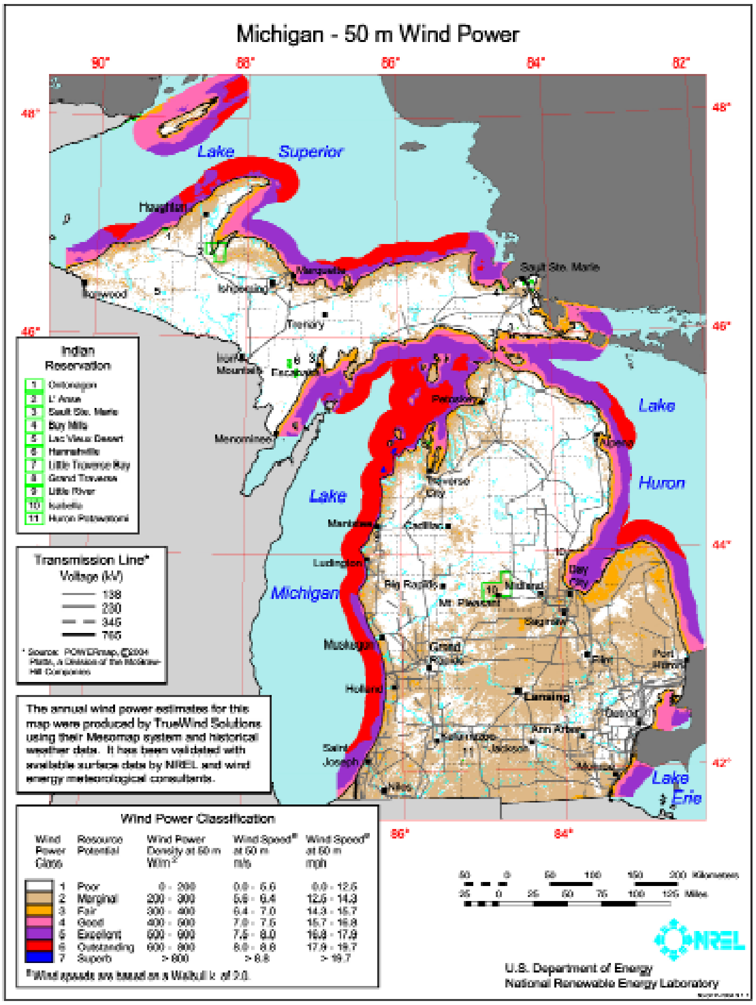


Figure 4-15. Michigan Wind Resource (NREL)

At Appalachian State University in North Carolina, a 100kW wind turbine was installed on campus. It had an expected 17% capacity factor and cost $533,000 to install. A photo is shown in the following figure.

Figure 4-16. Appalachian State 100 kW Wind Turbine Installation

Table 4-8. Wind Technology Characteristics.	
Capital Costs ($/kW)	$2,525 to $5050
Applicability to the Lansing, Michigan region	Marginal wind resource
Applicability for a university campus	Likely off-campus site
Readiness	mature technology with operational and maintenance history

4.10 Fuel Cell

In addition to space exploration and consideration for future automotive power, fuel cells continue to be considered for power generation to meet permanent and intermittent power demands. However, due to their early developmental status and uncertainty related to reliability and cost, fuel cell technologies are not considered to be commercially proven alternatives.

Fuel cells convert hydrogen-rich fuel sources directly into electricity through an exothermic electrochemical reaction. Fuel cell power systems have the promise of high efficiencies because they are not limited by the Carnot efficiency that limits thermal energy cycles. Fuel cells can sustain high efficiency operation even at part load and can co-generate hot water for use in low temperature heating applications such as building space conditioning. The construction of fuel cells is inherently modular, making it easy to size plants according to power requirements. There are several fuel cell technologies under development.

Whole Foods Market has a UTC Power, PureCell Model 200 power plant in its new 46,000-square-foot store in Glastonbury, Connecticut, Whole Foods Market will generate 50 percent of the electricity and heat and nearly 100 percent of the hot water needed to operate the store on-site.

The PureCell™ Model 200 power solution

Source: http://www.utcfuelcells.com/fs/com/bin/fs_com_Page/0,11491,0122,00.html

Figure 4-17. Fuel Cell Package

Commercial fuel cell plants are typically fueled by natural gas, which is converted to hydrogen gas in a reformer at temperatures of 600-800° C.

Table 4-9. Fuel Cell Technology Characteristics.	
Capital Costs ($/kW)	$2,000 to $2,500
Applicability to the Lansing, Michigan region	Applicable
Applicability for a university campus	Applicable to building-size applications
Readiness	new but full scale installed technology with short operating history

4.11 Run of River Hydro/Hydrokinetic

The Grand River runs through Lansing, MI. the water flowing in the river could provide a source of power for generation. A large "high-head" dammed project would probably not be considered for many environmental, economic and cultural reasons. Two other possible alternatives are run-of-river hydro and in-river hydrokinetic power production.

The Federal Power Act provides FERC with the exclusive authority to license non-federal water power projects on navigable waterways and federal lands. FERC issues licenses (valid for up to 50 years) for constructing, operating, and maintaining nonfederal hydropower projects. A FERC license would be required for any Run of River or Hydrokinetic project on the Grand River.

Hydrokinetic

Hydrokinetic renewable energy is still in early stages of concept design and development compared to other established renewable energy options. A number of large scale devices are in the research, development, and demonstration phase, and are on the cusp of being installed commercially. Hydrokinetic projects generally consist of many small turbines connected electrically to form a larger nameplate capacity project.

The four main categories that characterize hydrokinetic devices currently under development, as determined by the "prime-mover" (or principle defining characteristic) are as follows:

- Horizontal Axis Axial Flow Turbine (HAA).
- Vertical Axis Cross Flow Turbine (VAC).
- Oscillating Hydrofoil (OH).
- Venturi Devices (V).

The mechanical energy from the prime-mover may be converted to electricity via a number of conversion steps (e.g. hydraulic, direct electrical, mechanical) embodied in a "power-train."

There is a University of Michigan patented, hydrokinetic power generating device which harnesses hydrokinetic energy of river and ocean currents through a physical phenomenon of vortex induced vibration. Named VIVACE, this device is unlike water turbines as it does not use propellers. VIVACE taps the energy of water current flows around cylinders by inducing transverse motion. The energy contained in the movement of the cylinder is then converted to electricity. Vortex Hydro Energy has exclusive license to commercialize the patent. Vortex induced vibration is a transformational technology which taps into a vast new source of clean and renewable energy, that of water currents as slow as 2 to 3 knots. Such slow flow velocities have been previously off limits to conventional turbine technologies which target rivers with water currents greater than 4 knots. The vast majority of river/ocean currents in the United States are slower than 3 knots.

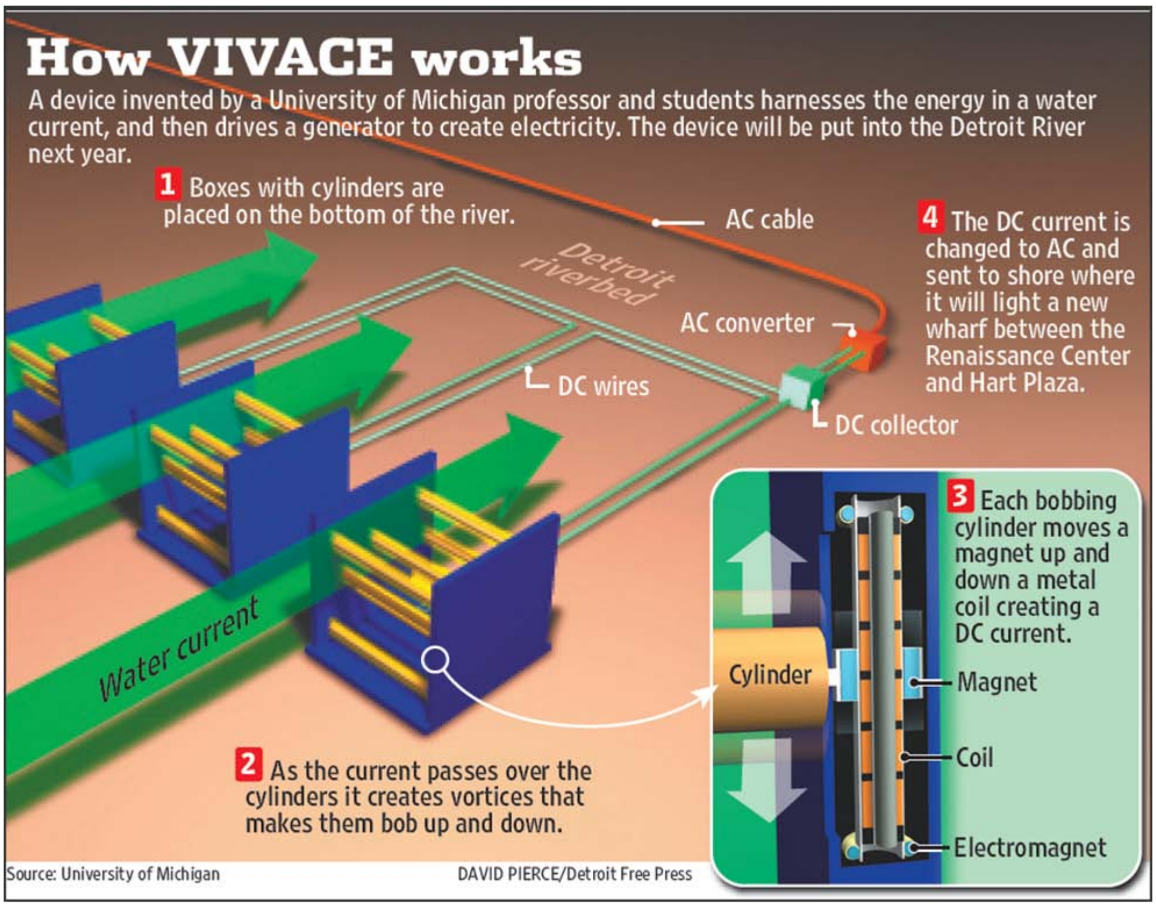


Figure 4-18. Vortex Induced Vibration Energy in Rivers

The hydrokinetic market has significant potential, but has been largely limited by the extreme conditions in which the devices need to be installed and operate. The shallow water (<20 m) market does not generally have the same potential as the deep water market (>20 m), with generally more constrained sites and generally lower flows, especially in river applications. However, the benefits of the shallow sites include reduced competition, easier installation and maintenance, reduced mooring costs, and proximity to the end user; therefore, less underwater cabling is required.

Free Flow Power Company is in the process of obtaining FERC licenses for several river locations in the U.S. Proposed projects are in the 10 MW size range. In Hastings, MN Hydro Green Energy LLC installed the first hydrokinetic power plant, a 125kW unit in Mississippi Lock and Dam No. 2.

Table 4-10. Hydrokinetic Technology Characteristics.

Capital Costs ($/kW)	Little available data
Applicability to the Lansing, Michigan region	Possible for consideration on the Grand River
Applicability for a university campus	Likely off-campus facility
Readiness	Conceptual technology with theoretical results

Run of River or Low-head Hydro

In situations where a dam is not feasible for a conventional “high-head” hydroelectric facility, it is possible to divert water out of the natural waterway, through a penstock, and back to the waterway. Such “run-of-river” or “diversion” applications allow for hydroelectric generation without the impact of damming the waterway.

Hydroelectric generation is regarded as a mature technology and is already established throughout the U.S. It is not expected to experience any significant technical advancement due to its already high reliability and efficiency. Turbine efficiencies and costs have remained somewhat stable, but construction techniques and their associated costs continue to change. Capacity factors are highly resource dependent and can range from 10 percent to more than 90 percent, although they typically range from 40 percent for run of river application to 60 percent for a facility with an impoundment structure. Capital costs also vary widely with site conditions.

The damming or diverting of rivers for hydroelectric applications may have significant environmental impacts. One major issue involves the migration of fish and disruption of spawning habits. A second issue involves flooding existing valleys that often contain wilderness areas, residential areas, or archeologically significant remains. There are also concerns about the consequences of disrupting the natural flow of water downstream and disrupting the existing ecosystems.

Table 4-11. Hydroelectric Technology Characteristics.	
Capital Costs ($/kW)	2,500 to 5,300
Applicability to the Lansing, Michigan region	Possible for consideration on Grand River
Applicability for a university campus	Off-site location
Readiness	mature technology with operational and maintenance history

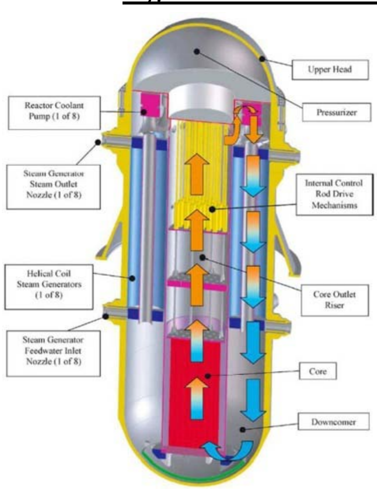
4.12 Small Scale or Mobile Nuclear

The pressure of climate control is contributing to an interest to resume nuclear energy for future central plant concepts. Nuclear power production is emission free, but has high public safety risk related to waste disposal and emergency operation. Historically nuclear power requires high capacity cost and low operating costs and has been limited to public utilities and the military. Recent manufacturing efforts indicate an interest in developing mobile nuclear units for application in municipal and industrial sites with lower capital cost and where refueling and waste storage will be performed off site from the production operations.

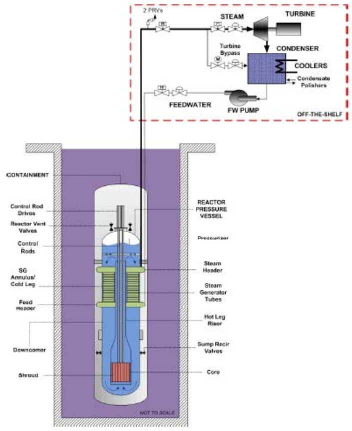
Small and Midsize Advanced Modular Reactor Developments

A number of other small modular reactors (SMRs) are being currently proposed by various reactor designers for the commercial power market. They include the following leading candidates for the US domestic market:

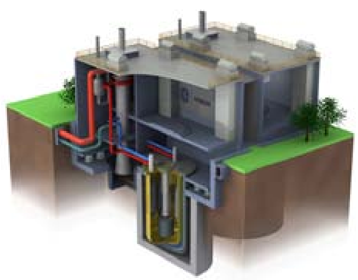
1. **<u>Light-water cooled Reactor (LWR) designs:</u>**



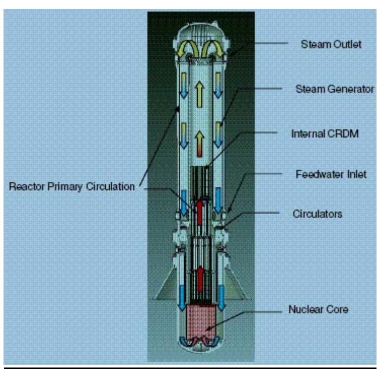
335 MW(e) *International Reactor Innovative and Secure (IRIS), Westinghouse Electric Company* Pressurized water reactor with reactor vessel, helical-coil steam generators, reactor coolant pumps, and pressurizer within a reactor vessel which is enclosed in a spherical steel containment vessel. 3 to 3.5-year refueling cycle.



40 MW(e) *NuScale, NuScale Power Inc.* Natural circulation light water reactor with the reactor core and helical coil steam generators located in a common reactor vessel. The reactor vessel is submerged in a pool of water. The reactor design is based on MASLWR (Multi-Application Small Light Water Reactor) developed at Oregon State University in the early 2000s. 2-year refueling cycle. Reactor is 9 feet OD by 45 feet tall, in an underground water filled reactor pool the bottom of which is 69 feet below the surface. Entire Nuclear Steam Supply System (NSSS) is 60 feet by 15 feet, prefabricated and shipped by rail, truck or barge. Ongoing pre-application meetings with NRC in FY2008 and FY2009. Design Certification application in 2011, with anticipated approval in 2014. Assuming a parallel ESP or COL, the first NuScale unit would be online in 2018.

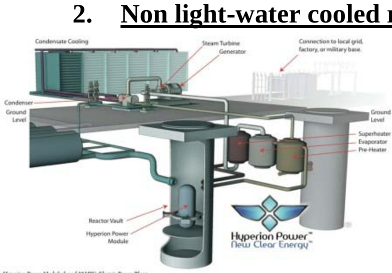


311 MW(e) *Power Reactor Innovative Small Module (PRISM), GE Hitachi Nuclear Energy* Liquid metal (sodium) cooled, underground containment on seismic isolators with a passive air cooling ultimate heat sink. Modular design with two reactor modules per power unit (turbine generator). NRC staff conducted pre-application review in early 1990s. 1 to 2-year refueling cycle.



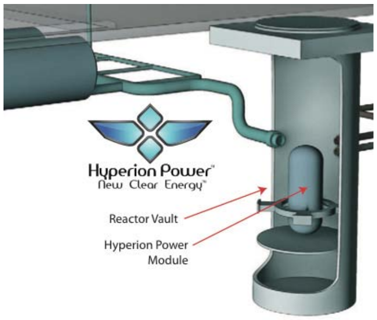
125 MW(e) *mPower, Babcock & Wilcox Company* a scalable, modular, passively safe, advanced light water reactor system. The modular design has the capacity to provide 125 MWe to 750 MWe or more for a five-year operating cycle without refueling, and is designed to produce clean, near-zero emission operations. The reactor and steam generator may be located in a single reactor vessel located in an underground containment. Passive safety systems, 5-year refueling cycle, used fuel stored in spent fuel pool for life of the reactor (60 years), North American shop-manufactured. Each B&W mPower reactor that is brought online will contribute to the reduction of approximately 57 million metric tons of CO_2 emissions over the life of the reactor. Three utilities have signed an agreement with B&W to get NRC approval of the design.

2. **<u>Non light-water cooled reactors (non-LWR) designs:</u>**



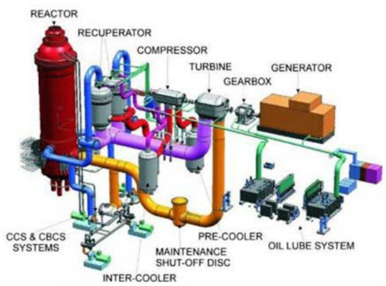
Hyperion Power Module-based 25MWe Electric Power Plant

25 MW(e) *Hyperion, Hyperion Power Generation, Inc.* Hyperion has licensed rights for the reactor design from LANL (Los Alamos National Laboratory). The Potassium heat pipes/light water cooled reactor uses a Uranium hydride fuel design. A conceptual design. NRC has had limited interactions with Hyperion and is awaiting further design work before scheduling pre-application meetings. 7 to 10-year refueling cycle. Reactor is 5 feet OD by 6.5 feet tall, totally sealed and buried underground, with power generation equipment at the surface. Based on TRIGA and SNAP reactor

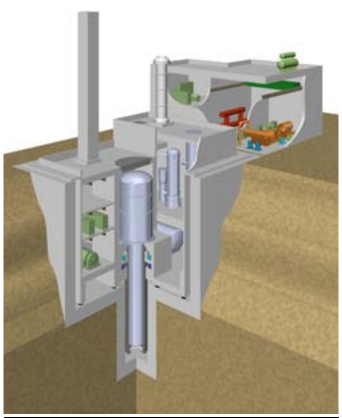


technologies cost is estimated at $37M each (2008 dollars). Supplier claims to have 100 "firm orders" but is short on plant details. Supplier's licensing schedule as follows:

- Summer 2009 -- Validation
- Oct 2009 -- NRC Pre-application Review begin
- Oct 2011 -- NRC Pre-application Review Complete, Design Certification application submitted
- Mar 2015 -- Anticipated DC approval
- Mar 2016 -- First Hyperion unit online (assuming parallel path for ESP or COL)



165 MW(e) *Pebble Bed Modular Reactor (PBMR), PBMR (Pty.), Ltd.* Modular design, high-temperature-gas-cooled (HTGR), pebble bed reactor with online refueling that generates electricity via a gas or steam turbine and which may also be used for process heat applications. The NRC completed a pre-application review on March 2002, per Exelon request. On April 2002 Exelon announced they would not be proceeding with the PBMR project. Licensing of a demonstration plant in South Africa is being reconsidered. Agreement with Chinese for cooperation in development. Online refueling design.



10 MW(e) *Super-safe, Small and Simple (4S), Toshiba Company* Small, sodium-cooled, underground reactor. Working with the city of Galena, AK as a potential COL partner. 30-year refueling cycle. Surface structure measures 72 feet by 52.5 feet, and 36 feet height. Ongoing pre-application meetings with NRC in FY2009. Ongoing pre-application meetings with the NRC, with Design Certification submittal in 2011. DC issued in 2014, and first 4S unit online in 2017.

Other HTGR reactor designs are being studied in the U.S. and world communities. The U.S. NRC currently expects to receive formal DC review applications for these designs sometime as early as FY 2011. The Design Certification (DC) process is expected to take several years before the reactor will be available for commercial development. Both the U.S. NRC and DOE have requested additional funding in FY2011 to support small modular reactor development and certification.

3. "Small" Reactor Reviews:

For Michigan State University, the NuScale 40 MW and the Hyperion Power 25 MW units would be appropriate sizes for the campus. There has been much media attention and speculation about the development of small reactors for use in applications other than large-scale power generation. The Nuclear Regulatory Commission has yet to receive any applications for such reactors. When, or if, formal applications are received, they will be subject to a very rigorous review process that will take several years to complete.

And submission of an application is no guarantee that the NRC – whose mission is to protect people and the environment – will find any particular design meets the agency's high safety and security standards.

The NRC is aware that Hyperion and others have proposed building such reactors. Hyperion advised the NRC it intended to provide technical reports on its proposal in the fall of 2009 as part of a pre-application review. That would only be the first step in a process that could take years and years. The licensing of new, small reactors is not just around the corner. The NRC's attention and resources now are focused on the large-scale reactors being proposed to serve millions of Americans, rather than smaller devices with both limited power production and possible industrial process applications.

In our innovative society it is not unusual for firms like Hyperion and others to propose reactor designs that are radically different from the existing generation of technology. And examining proposals for radically different technology will likely require an exhaustive review before the NRC could approve them as safe for use. Until such time as there is a formal proposal, the NRC will, as directed by Congress, continue to devote the majority of its resources to addressing the current technology base. The technology for small nuclear power remains in developmental stages. Commercial applications are being talked about beyond 2020.

Technology Availability

Small Scale Nuclear Development Timeline

Small and Midsize Advanced Modular Reactor (SMR) development is progressing under various development timelines. Some designs, like the IRIS, PRISM and 4S are well funded, and well along the development cycle. Other designs like NuScale, and Hyperion are still finalizing reactor details. Both the U.S. NRC and the U.S. DOE have requested additional funding in FY2011 to support SMR advanced reactor development and certification.

In the October 2009 Periodic Briefing Workshop, the U.S. DOE identified three sets of SMR designs and concepts based on design type, licensing and deployment schedule, and maturity of design:

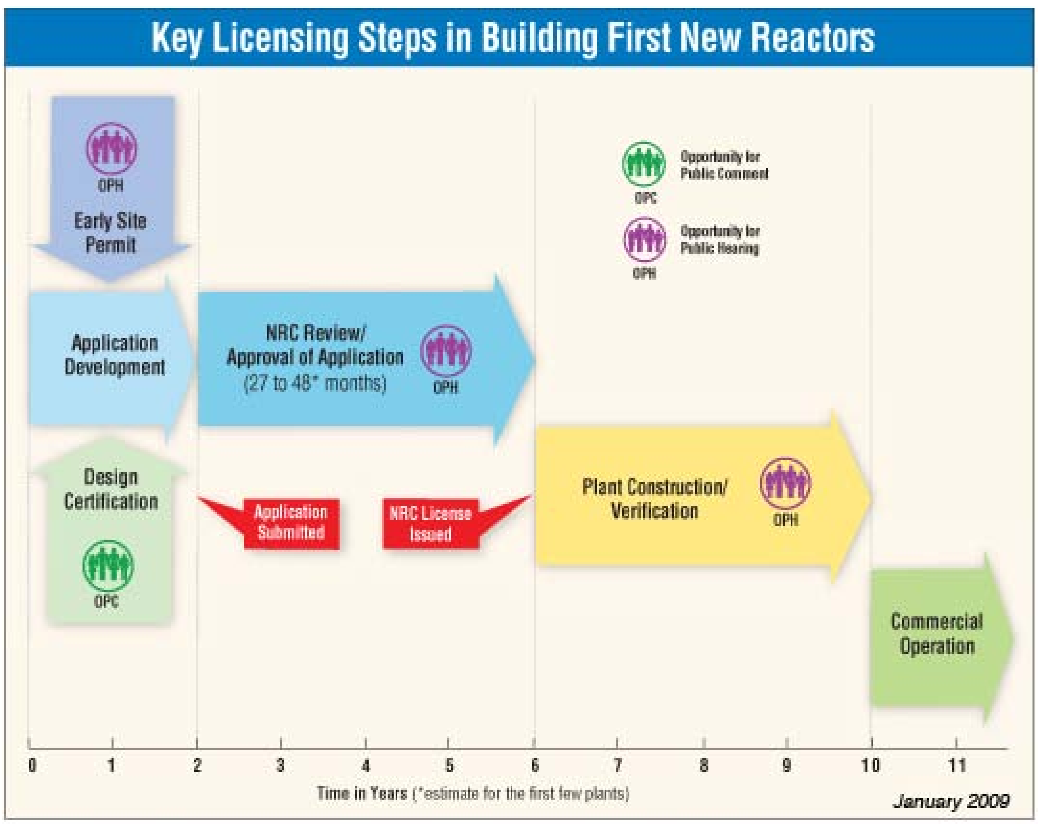
- LWR based designs
  5-10 years
- Non-LWR designs
  10-15 years
- Advanced Reactor Concepts and Technologies
  15-25 years

Considering the various Design, Regulatory, Legislative, and Construction steps involved in constructing a new SMR reactor, the commercial operation date for the first unit would not be expected before 2023. This assumes that the reactor receives a design certification by 2018 and the project site receives a Combined Construction and Operating License

(COL) by 2021. Construction is expected to be two to three years, due to the small modular design of the plants. Recent Licensing and Legislative actions are detailed below.

- **U.S. NRC Licensing**
  Periodic meetings are held by the U.S. NRC with all stakeholders (e.g.: developers, U.S. DOE, investors) to prepare for the expected reactor license submissions. Appendix A is the latest schedule published by the U.S. NRC showing potential advanced reactor licensing applications for design certification. The schedule shows NGNP, PBMR, IRIS, 4S, Hyperion, and NuScale timelines. Other concepts have yet to be scheduled for U.S. NRC review. Public hearings have yet to be scheduled, and would be expected to last six months to a year, depending on the participants.

  In addition to design certification, a new nuclear plant project must obtain a Connercial Operation License (COL). The COL process is shown in Figure 1, Key Licensing Steps in Building First New Nuclear Reactors, below.



The NRC's new licensing process offers multiple opportunities for public input.

Figure 4-19. NRC Licensing Process Timeline

The durations shown in Figure 5-1 reflect a large new nuclear project. A new SMR reactor project is expected to be shorter durations for licensing and construction. The first structural concrete pour, starting major plant construction, is linked to COL approval by the U.S. NRC.

- **U.S. Federal Legislation**
  In November 2009, Senator Bingaman introduced Senate Bill S.2812, amending EPA2005, to carry out programs to develop and demonstrate 2 small modular nuclear reactor designs (at least one under 50 MWe). S.2812 is called the Nuclear Power Act of 2021, and provides funding for up to 50% cost sharing of the development costs. This bill supplements an earlier bill S.2052 introduced by Senator Udall, titled Nuclear Energy Research Initiative Improvement Act of 2009. There appears to be strong support for both of these Senate bills. Michigan State University should track this legislation and be prepared to submit a proposal to become the demonstration site.

- **U.S. State Legislation**
  Various U.S. states are taking pro-nuclear initiatives to modify legislations and/or regulations, including repealing state laws restricting construction of nuclear reactors inside their state borders. In Michigan, House Bill (H.B.) 5524 was enacted in October 2008. The bill was part of a package of energy bills that enacted regulatory reform, a renewable portfolio standard, renewable tax credits and an energy optimization program. Regulatory reform is addressed in H.B. 5524, including the creation of a certificate of necessity for large capital investments, which will support construction of nuclear plants. The legislation is specifically targeted at construction of a new unit at DTE's Fermi station, but would also benefit efforts to construct a SMR reactor. Key elements of the bill include:
  - This legislation reforms the Electric Choice program capping at 10 percent the number of a utility’s customers lost to other non-utility suppliers.
  - The way in which rates are set is changed to eliminate, over five years, the subsidy by businesses of residential rates.
  - The bill creates deadlines for action by the Michigan Public Service Commission (MPSC) upon receiving a filing, including a 12-month deadline on rate case decisions. If this deadline is not met, a utility may implement a requested rate increase subject to some limitations.
  - MPSC is given authority to review proposed utility mergers and acquisitions in the state.
  - Utilities can apply for and receive a certificate of necessity for assets costing $5 million or more prior to construction or purchase that allows the MPSC to predetermine the prudence of the investment (including explicitly the need for the asset and the appropriateness of the fuel choice).

- A certificate of necessity will specify approved project costs that can be added to rates when the asset becomes operational. Cost overruns are subject to additional MPSC review and approval.
- The MPSC may allow interest payments on capital work in progress to be passed through in rates during construction for projects granted certificates of necessity. Equity used during construction shall be recognized and treated as allowance for funds used during construction, which means an accrued rate of return on the equity and the principal equity will be applied to rates when the asset is operational.

Table 4-12. Small Scale Nuclear Technology Characteristics.

Capital Costs ($/kW)	$11,000 /kW
Applicability to the Lansing, Michigan region	Applicable
Applicability for a university campus	Applicable
Readiness	Emerging Technology, 8 years to design certification, 2-3 years for construction of first unit

5.0 Distributed Generation Options

New technologies feature concepts in distributed generation where energy is generated closer to the point of consumption, avoiding system losses in the distribution system. Distributed generation concepts often will utilize a portfolio of technologies in an attempt to maximize production scenarios. Some current distributed generation concepts, such as solar and wind, are viable only for consumption reduction. They can't be depended on for supply of energy demand. Many aspects of distributed generation will be reviewed with new space construction with LEED certification goals.

The movement of centralized energy generation to distributed generation will create capital expenditure to revise existing building infra structures. Step up power transformation with current invertors and batteries may be needed depending on the system design.

5.1 Natural Gas in Place of Coal

Natural gas can be used instead of coal to generate steam for thermal and electricity production in the central plant or for thermal use in a distributed steam generation approach. In the distributed generation approach, a remote boiler could supply steam to one building or it could supply steam into the existing campus distribution header to supplement the steam supplied from the central plant. High efficiency natural gas boilers distributed around the campus could reduce or eliminate the steam demand from the coal fired boilers in the T. B. Simon Power Plant. Natural gas combustion will provide 50% reduction in carbon dioxide emissions when compared to coal firing for a unit of steam produced at the same thermal efficiency. Natural gas will also provide significant reduction in SO_x and NO_x emissions. However, long term forecasts for natural gas predict pricing at $6-8/mcf (Roger Smith, Black & Veatch, Coal Outlook Oct 26, 2009) which is 50-100% higher than historical coal prices.

Table 5-1. Natural Gas – Combustion Turbine Technology Characteristics.

Capital Costs ($/kW)	$1,200/net kW
Applicability to the Lansing, Michigan region	Applicable
Applicability for a university campus	Applicable
Readiness	Commercially Available

5.2 Solar Photovoltaic

PV systems convert sunlight directly into electricity. The conversion of sunlight into electricity is known as the photovoltaic effect, and the materials and processes involved are very similar to semiconductors. The power produced depends on the material involved, the intensity of the solar radiation incident on the cell, and the cell temperature. Single or polycrystalline silicon cells are most widely used today. Single crystal cells are manufactured by growing single crystal ingots, which are sliced into thin cell-sized wafers. The cost of the crystalline material is significant. The production of polycrystalline cells, which are made from cast material rather than grown crystals, can cut material costs with some reduction in cell efficiency. Thin film modules, which are significantly less expensive but not as efficient, are also being used for large scale solar applications.

A PV system has two critical components: solar modules and inverters. The other important components include mounting system and hardware, disconnect switches, meters, and monitoring equipment. Solar modules convert sunlight directly into electricity, and the inverter converts the direct current (dc) electricity from the modules into alternating current (ac) electricity used by the electric grid.

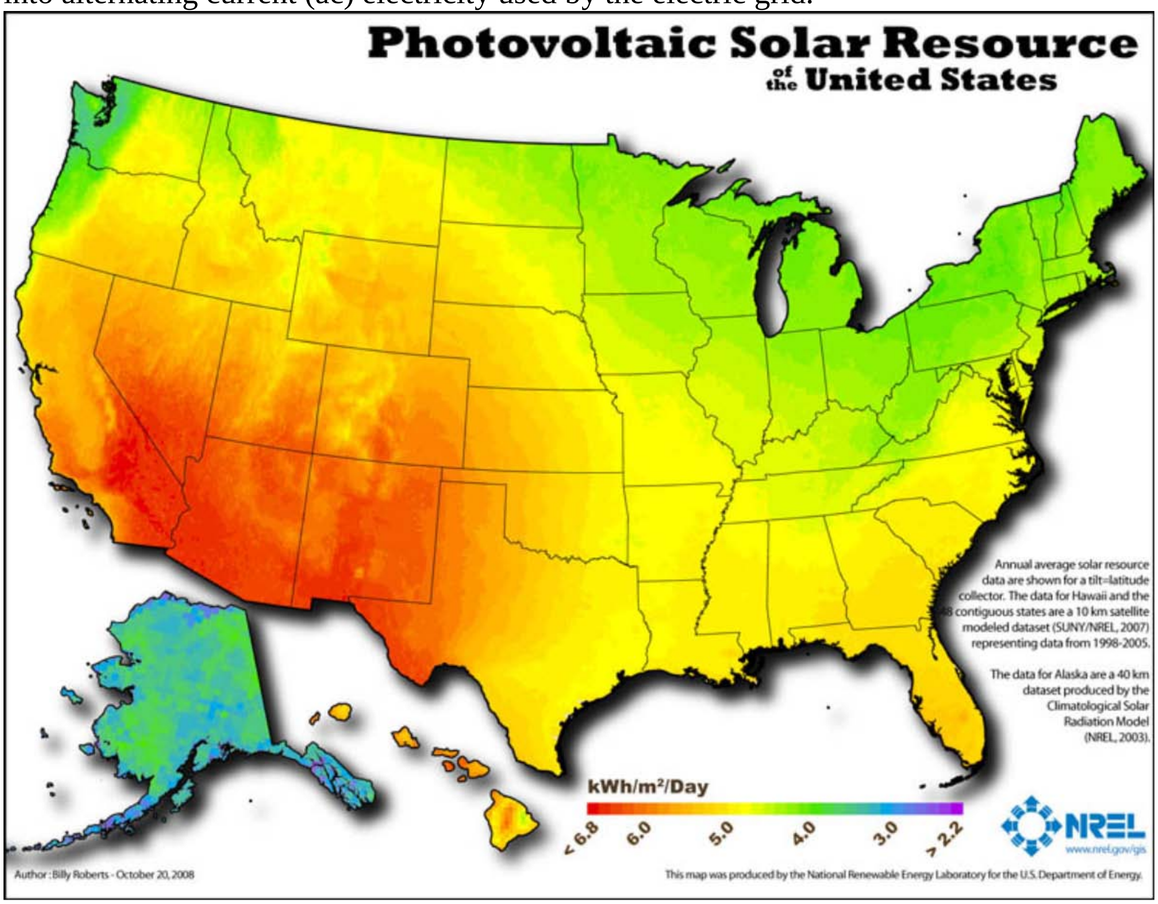


Figure 5-1. U.S. Solar Resource for Flat-Plate Photovoltaics.

For the University campus, PV system designs would need to be based on the estimation of useful day lighting. Physical Plant's Energy and Environmental Engineer estimates, based on Michigan geographic location, 400 to 500 acres of panels would be required to support the existing 61.4 MW of campus electric demand.

The total existing roof space is approximately 8 million sq feet (source Physical Plant Maintenance Services roofing Dept). Since much of the roof space is currently used for other process functions the potential usable acreage would be significantly less, perhaps 30% of the total or 55 acres. So PV maximum potential using existing roof area is 11-13 % of the demand.

Even though campus building roof PV panels would not be able to serve all of the campus electricity demands, utilizing the roofs could supplement the demands building-by-building as distributed on-site generation. Traditional wisdom in the solar industry has been that solar photovoltaic (PV) systems are appropriate for small distributed systems, and there is more experience with these applications. More recently, PV systems are being constructed in larger sizes up to and including utility-scale applications, and those are discussed in section 5 Central Plant Options.

Figure 5-2. Solar PV Collectors on House Roof

Figure 5-3. Solar PV Collectors on Tree Sculpture

The demonstrated PV efficiency on the MSU campus using monocrystalline silicon solar cells in an anodized aluminum frame with tempered glass face is 10% (based on 30 kv at MSU Recycling). Since PV can only provide electricity during periods of sunlight, supplemental energy systems would be required for the balance of the electrical demand and the variability of supply using PV. Solutions which are heavily dependent on PV will require additional concepts to maintain building heating systems.

The cost of solar PV systems has been steadily decreasing over the past few years. The following figure illustrates the trend.

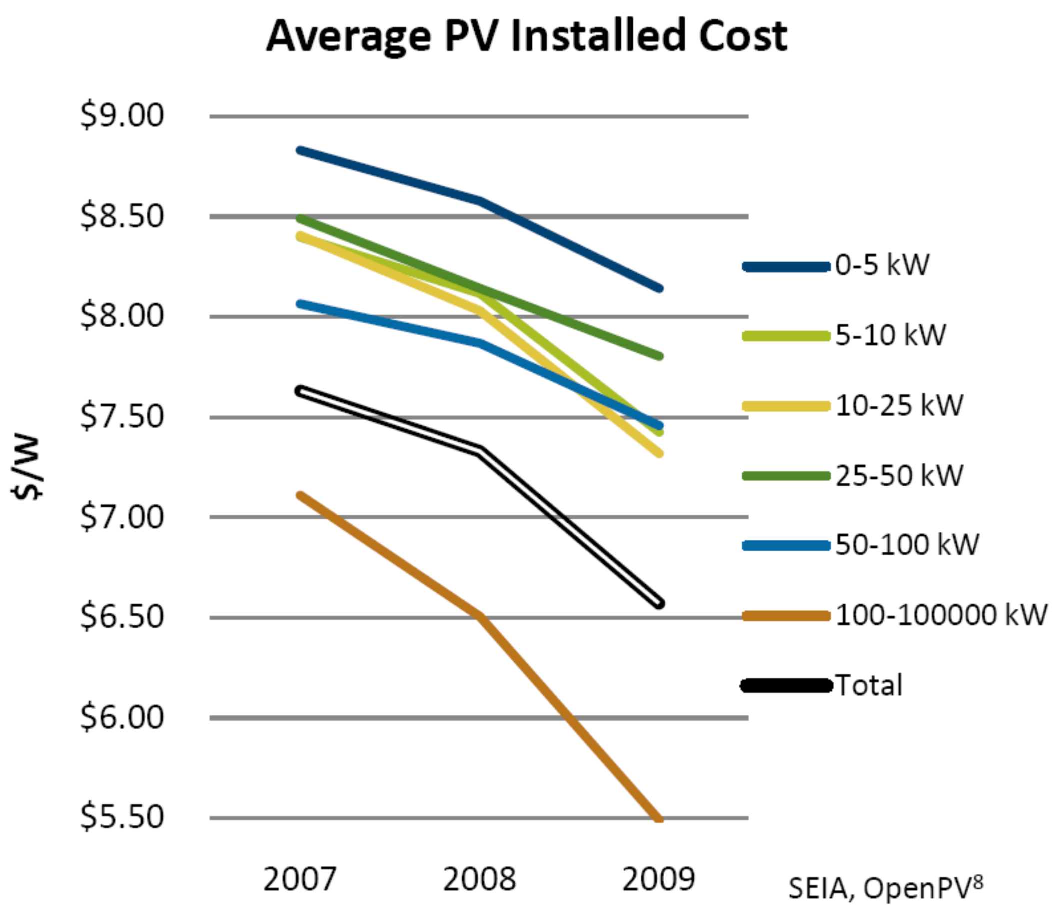


Figure 5-4. Average PV System Installed Cost

For planning purposes the supplemental system sizing would be based on the assumption of minimum PV output during peak demand periods.

Table 5-2. Photovoltaic Technology Characteristics.

Capital Costs ($/kW)	$4,000 - $6,000
Applicability to the Lansing, Michigan region	Adequate resource for flat plate technology
Applicability for a university campus	Suitable
Readiness	mature technology with operational and maintenance history

Notes:
[a] Most of the U.S. has adequate or better resource for solar photovoltaics.

5.3 Solar Hot Water Heating

Among solar thermal technologies, water heating utilizes medium temperature technologies between 140F and 180F. High temperature solar thermal would be for steam generation in a power generating station, and low temperature would be for solar assisted heat pump systems.

Solar water heating became a growth industry following the oil embargo of the 1970's, but stalling in the 1980's serving mostly single family residences. Poor quality of components and installations combined with falling energy pricing caused the collapse of the U.S. market 20 years ago; however, technology development continued in Germany and China.

Now, starting in May 2010, solar water heating programs in California are promoting a rebirth of the industry driven by legislative and regulatory initiatives in that and other states targeting commercial and institutional customers. Incentives are directed to reduce the use of natural gas and electric resistance energy for water heating. Schools and universities in the USA have already become the single largest market for solar water heating systems, followed by multi-family residences and private commercial buildings. Today these customers are using medium temperature solar water heating systems for direct potable water heating, swimming pool water heating, and to a lesser degree building space heating.

Solar hot water systems typically consist of solar thermal collectors, water storage tank, pumps and controls. Most thermal collectors are of the flat plate type, which heat either water directly or a heat-transfer fluid, such as propylene glycol. Flat plate collectors require more space than do concentrating collectors, but flat plate collectors can continue to receive beneficial solar energy on overcast days, while concentrating collectors do not.

For Michigan State University, flat plate solar hot water collectors may be applied to provide direct heating or preheating of potable water and of pool water heating in applicable buildings. For such buildings with high heating water demands, rooftop installations of solar hot water systems may be more beneficial than rooftop installations of solar PV systems. The MSU I.M. building has pools and hot water shower facilities. I.M. West has an outdoor pool of approximately 800,000 gallons requiring low to medium temperature heat.

5.4 Solar Air Heating

Heat from the sun can be used to warm incoming ventilation air required for occupied buildings or for drying processes during the winter months. The effectiveness of solar heating of any media increases inversely to the temperature of the incoming media. Typically, the lowest temperature media to be heated by the sun will be the outdoor air which is to be supplied into a building. Therefore buildings with design features to preheat ventilation air utilizing the sun can be highly effective.

Most of the MSU campus buildings require ventilation air. Residences require ventilation 24 hours per day. Classrooms and lecture halls may require ventilation only during day time occupancies. Laboratories may require high rates of ventilation. Finally, there may be some agricultural buildings which require very high rates of ventilation 24 hours per day and some which require heated outdoor air for drying operations. For buildings with air-to-air exhaust heat recovery, typically, outdoor air preheating is required to prevent ice accumulation on the exhaust side of the heat exchanger. All of these buildings are candidates for solar air preheating.

The solar air heating features begin with a south facing wall having an exterior perforated metal cladding to allow the inflow of the outdoor ventilation air. This cladding is installed several inches from the building wall creating an air cavity. Features of the external cladding may also include glazing to maximize the solar heating of the space between the exterior cladding and the building wall or for an architectural effect. The metal cladding is heated by the sun’s rays and the perforations are designed to let in only the outdoor air within the heated boundary layer covering the area of the wall. The system functions most effectively on cold sunny days with still air. The photograph below shows a solar air heating wall.

Figure 5-5. Solar Ventilation Air Heating Installation

The solar heated air rises inside the cavity between the exterior cladding and the building wall and is collected by the building ventilation system located inside the building at its upper level or located on the building roof. The diagram below shows the solar preheating feature.

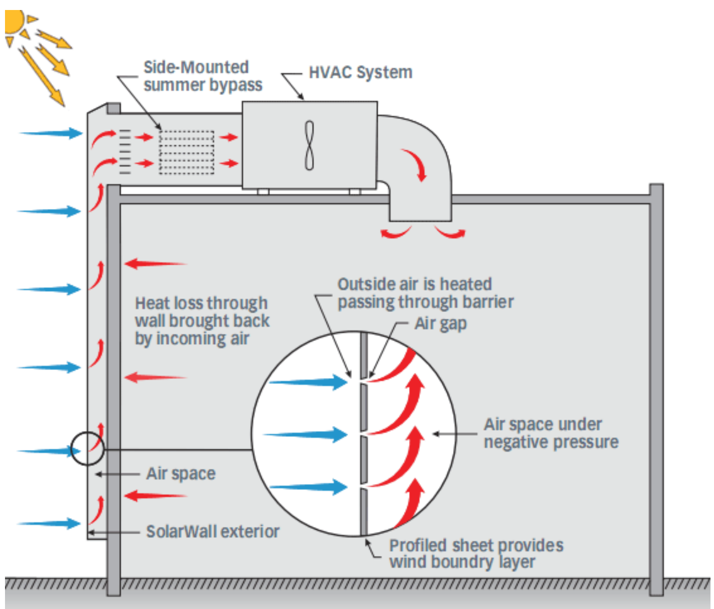


Figure 5-6. Solar Ventilation Air Heating Diagram -SolarWall®

The solar preheat system will preheat the ventilation air between 30 and 70°F on a sunny day and less on a cloudy day. Any amount of solar preheating reduces the building's demand for ventilation air heating, and may even eliminate ventilation heating energy at times. For air-to-air heat recovery systems, solar air preheating may often eliminate the need for ice prevention preheating.

5.5 Wind

Wind power systems convert the movement of air to power by means of a rotating turbine and a generator. Wind power has been among the fastest growing energy sources over the last decade, with around 30 percent annual growth in worldwide capacity over the last five years. The World Wind Energy Association states that cumulative worldwide wind capacity is now estimated to be more than 121,000 MW. Total installed wind capacity in the United States exceeded 25,300 MW as of January 2009. The U.S. wind market has been driven by a combination of growing state mandates and the PTC, which provides an economic incentive for wind power. The PTC has been renewed several times and is currently set to expire on December 31, 2012.

Typical utility-scale on-shore wind energy systems consist of multiple wind turbines that range in size from 1.5 MW to 3 MW on-shore. Utility-scale wind energy system installations may total 5 MW to 300 MW. The use of single, smaller turbines is also common in the United States for powering schools, factories, water treatment plants, and other distributed loads. Community wind projects in the U.S. involve a cluster of turbines, sometimes as part of a larger utility-scale wind farm, to provide power for a town, a large campus or other facility.

Wind is an intermittent resource, with average capacity factors ranging from 25 to 40 percent. The capacity factor of an installation depends on the wind regime in the area and the energy capture characteristics of the wind turbine. Capacity factor directly affects economic performance; thus, reasonably strong wind sites are required for cost-effective installations. Since wind is intermittent, it cannot be relied upon as firm capacity for peak power demands. To provide a dependable resource, wind energy systems may be coupled with some type of energy storage to provide power when required, but this is not common and adds considerable expense to a system.

For Michigan State University the best opportunities to site wind turbines to maximize utilization on its own real estate may be on farm property south of the power house where wind velocity would be undisturbed by buildings and trees common to most campus areas. However, Figure 6-7 tells us that even these sites in the Lansing area are poor to marginal for producing wind power. For Michigan, the lake shore areas offer the greatest potential for economical power production utilizing the wind.

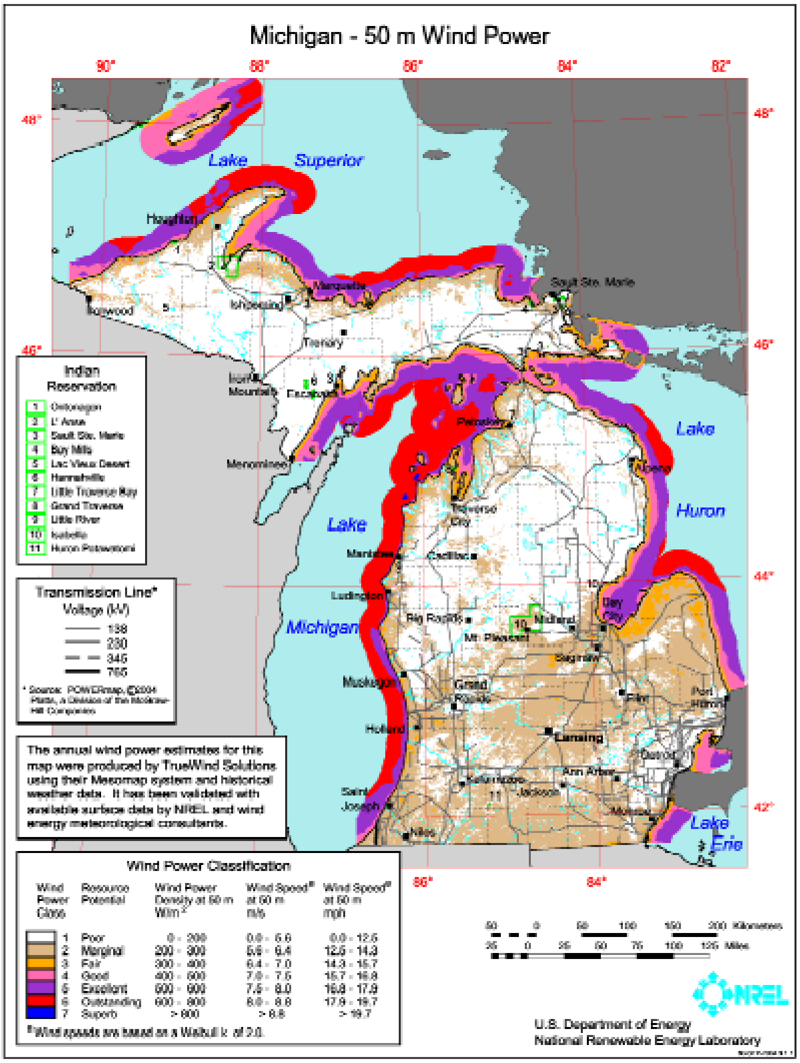


Figure 5-7. Michigan Wind Resource (NREL).

Table 5-3. Wind Technology Characteristics.	
Capital Costs ($/kW)	$2,525 to $5,050
Applicability to the Lansing, Michigan region	Marginal wind resource
Applicability for a university campus	Likely off-campus site
Readiness	mature technology with operational and maintenance history

5.6 Fuel Cell

In addition to space exploration and consideration for future automotive power, fuel cells continue to be considered for power generation to meet permanent and intermittent power demands. However, due to their early developmental status and uncertainty related to reliability and cost, fuel cell technologies are not considered to be commercially proven alternatives.

Fuel cells convert hydrogen-rich fuel sources directly to electricity through an electrochemical reaction between hydrogen and oxygen. In the protonic exchange membrane (PEM) type of fuel cell, the electrochemical reaction takes place inside a membrane electrode assembly (MEA). The MEA is essentially a polymer electrolyte membrane sandwiched between two catalysts. The hydrogen fuel enters the anode catalyst where the catalyst activates the hydrogen molecules to release their electrons, setting up positive and negative charges, thus inducing a flow of the electrons. Oxygen enters the cathode catalyst. As the electrons flow from the anode to the cathode catalysts, they produce direct current electricity. The hydrogen molecules that released the electrons at the anode migrate as ions to the cathode through the electrolyte, bonding with the oxygen molecules to form water there. The PEM fuel cell is compact making it suitable for mobile applications.

The solid oxide fuel cell (SOFC) uses a tubular design. However, the electrical resistance of tubular SOFCs is high making the specific power output (W/cm2) and volumetric power density (W/cm3) low. These low power densities make tubular SOFCs suitable only for stationary power generation. Planar SOFCs, in contrast, are capable of achieving very high power densities. Mass customization of planar SOFCs is being pursued in the U.S. Department of Energy's Solid State Energy Conversion Alliance (SECA) to lower cost. This concept involves the development of a 3–10 kW size core planar SOFC module that can be mass produced and then combined for different size applications in stationary power generation, transportation, and military market sectors, thus eliminating the need to produce custom-designed and inherently more expensive fuel cell stacks to meet a specific power demand.

There is some inefficiency in the energy conversion from hydrogen fuel to electrical energy in all fuel cells, and that inefficiency produces heat. Water and heat are the only byproducts generated by a fuel cell which runs on hydrogen.

Commercial fuel cell plants are typically fueled by natural gas, landfill gas, or other biogas, which is converted to hydrogen gas in a reformer at temperatures of 600-800°C. In the reformulation, however, the carbon component of the original gas fuel will be converted to carbon dioxide becoming an emission of the overall fuel cell process. Figure 6-8 shows a BloomEnergy packaged SOFC fuel cell which runs on 15 psig natural gas and produces 100 kW of 480V 3-phase electricity.

Figure 5-8. BloomEnergy SOFC Packaged Fuel Cell

Fuel cell power systems offer the promise of high energy conversion efficiencies because they are not limited by the Carnot cycle efficiency that limits heat cycles commonly used for power production. Fuel cells can sustain high efficiency operation even at part load. The construction of fuel cells is inherently modular, making it suitable for sizing plants according to power requirements in a distributed generation scenario.

Table 5-4. Fuel Cell Technology Characteristics.

Capital Costs ($/kW)	$2,000 to $2,500
Applicability to the Lansing, Michigan region	Applicable
Applicability for a university campus	Applicable to building-size applications
Readiness	new but full scale installed technology with short operating history

5.7 Micro Turbines

The microturbine is essentially a small version of the combustion turbine. It is typically offered in the size range of 30 to 60 kW. These turbines were initially developed in the 1960s by Allison Engine Co. for ground transportation. The first major field trial of this technology was in 1971, with the installation of turbines in six Greyhound buses. By 1978, the buses had traveled more than a million miles, and the turbine engine was viewed by Greyhound management as a technical breakthrough. Since this initial application, microturbines have been used in many applications, including small-scale electric and heat generation in industry, waste recovery, and continued use in vehicles.

Microturbines operate on a principle similar to that of larger combustion turbines. Atmospheric air is compressed and heated with the combustion of fuel, then expanded across turbine blades, which in turn operate a generator to produce power. The turbine blades operate at very high speeds in these units, up to 100,000 rpm, versus the slower speeds observed in large combustion turbines. Another key difference between the large combustion turbines and the microturbines is that the compressor, turbine, generator, and electric conditioning equipment are all contained in a single unit about the size of a refrigerator, versus a unit about the size of a railcar. The thermal efficiency of these smaller units is currently in the range of 20 to 30 percent, depending on the manufacturer, ambient conditions, and the need for fuel compression; however, efforts are under way to increase the thermal efficiency of these units to around 40 percent.

These systems have been used in many remote power applications around the world to bring reliable generation outside of the central grid system. In addition, these units are currently being used in several landfill sites to generate electricity with Landfill Gas (LFG) fuel to power the facilities on the site. For example, the Los Angeles Department of Water and Power recently installed an array of 50 microturbine generators at the Lopez Canyon landfill. The project has a net output of 1,300 kW. TECO (Tampa, FL) currently employs a 30 kW micro turbine using landfill gas to produce electricity and reduce methane gas release to the atmosphere.

Microturbines offer fuel flexibility; fuels suitable for combustion include natural gas, ethanol, propane, biogas, and other renewable fuels. The minimum requirement for fuel heat content is around 350 Btu/scf, depending upon microturbine manufacturer.

Table 5-5. Microturbine Technology Characteristics.

Capital Costs ($/kW)	$2,000 - $4,000[a]
Applicability to the Lansing, Michigan region	Applicable
Applicability for a university campus	Applicable
Readiness	new but full scale installed technology with short operating history

Notes:
[a] limited cost information

5.8 Geothermal Heat Pump

There are two methods in which geothermal heat may be employed as an energy source for a customer. The first way—and the way most commonly thought of—is to draw high temperature heat from the earth's core for direct heating and steam generation. The heat from hot ground areas, such as Yellowstone National Park and the volcanic island of Iceland are examples of geothermal sources. Iceland generates most of the electricity used on the island utilizing high temperature geothermal energy.

The second way to utilize geothermal energy—and the way most commonly available—is to use the earth as a low temperature heat source in the winter and heat sink in the summer in connection with heat pump technology. By using water source heat pumps, low temperature heat, say 40 to 50°F, can be extracted from the earth and then increased in temperature to a temperature, say 110 to 130°F, suitable for space heating.

Low temperature geothermal heat with heat pump systems require a way to get the heat from deep in the ground, and there are several ways, which are:

- well water extraction
- deep river water extraction
- horizontal closed loop field
- vertical closed loop field

For Michigan State University, the ground is not suitable for geothermal direct heating, but it may be suitable low temperature heat extraction and temperature boosting with heat pump technology. The campus has a building under construction which will use this technology. The heat pump approach was selected as a lower cost alternative to extending the campus steam loop to the building or to using natural gas combustion for direct heating.

5.9 Run of River Hydro/Hydrokinetic

The Grand River runs through Lansing, MI. The water flowing in the river could provide a source of power for generation. A large "high-head" dammed project would probably not be considered for many environmental, economic and cultural reasons. Two other possible alternatives are run-of-river hydro and in-river hydrokinetic power production.

The Federal Power Act provides FERC with the exclusive authority to license non-federal water power projects on navigable waterways and federal lands. FERC issues licenses (valid for up to 50 years) for constructing, operating, and maintaining nonfederal hydropower projects. A FERC license would be required for any Run of River or Hydrokinetic project on the Grand River.

Hydrokinetic

Hydrokinetic renewable energy is still in early stages of concept design and development compared to other established renewable energy options. A number of large scale devices are in the research, development, and demonstration phase, and are on the cusp of being installed commercially. Hydrokinetic projects generally consist of many small turbines connected electrically to form a larger nameplate capacity project.

The four main categories that characterize hydrokinetic devices currently under development, as determined by the "prime-mover" (or principle defining characteristic) are as follows:

- Horizontal Axis Axial Flow Turbine (HAA).
- Vertical Axis Cross Flow Turbine (VAC).
- Oscillating Hydrofoil (OH).
- Venturi Devices (V).

The mechanical energy from the prime-mover may be converted to electricity via a number of conversion steps (e.g. hydraulic, direct electrical, mechanical) embodied in a "power-train."

The hydrokinetic market has significant potential, but has been largely limited by the extreme conditions in which the devices need to be installed and operate. The shallow water (<20 m) market does not generally have the same potential as the deep water market (>20 m), with generally more constrained sites and generally lower flows, especially in river applications. However, the benefits of the shallow sites include reduced competition, easier installation and maintenance, reduced mooring costs, and proximity to the end user; therefore, less underwater cabling is required.

Free Flow Power Company is in the process of obtaining FERC licenses for several river locations in the US. Proposed projects are in the 10 MW size range. In Hastings, MN Hydro Green Energy LLC installed the first hydrokinetic power plant, a 125kW unit in Mississippi Lock and Dam No. 2.

Table 5-6. Hydrokinetic Technology Characteristics.	
Capital Costs ($/kW)	Little available data
Applicability to the Lansing, Michigan region	Possible for consideration on the Grand River
Applicability for a university campus	Likely off-campus facility
Readiness	Conceptual technology with theoretical results

Run of River or Low-head Hydro

In situations where a dam is not feasible for a conventional "high-head" hydroelectric facility, it is possible to divert water out of the natural waterway, through a penstock, and back to the waterway. Such "run-of-river" or "diversion" applications allow for hydroelectric generation without the impact of damming the waterway.

Hydroelectric generation is regarded as a mature technology and is already established throughout the U.S. It is not expected to experience any significant technical advancement due to its already high reliability and efficiency. Turbine efficiencies and costs have remained somewhat stable, but construction techniques and their associated costs continue to change. Capacity factors are highly resource dependent and can range from 10 percent to more than 90 percent, although they typically range from 40 percent for run of river application to 60 percent for a facility with an impoundment structure. Capital costs also vary widely with site conditions.

The damming or diverting of rivers for hydroelectric applications may have significant environmental impacts. One major issue involves the migration of fish and disruption of spawning habits. A second issue involves flooding existing valleys that often contain wilderness areas, residential areas, or archeologically significant remains. There are also concerns about the consequences of disrupting the natural flow of water downstream and disrupting the existing ecosystems.

Table 5-7. Hydroelectric Technology Characteristics.	
Capital Costs ($/kW)	2,500 to 5,300
Applicability to the Lansing, Michigan region	Possible for consideration on Grand River
Applicability for a university campus	Off-site location
Readiness	mature technology with operational and maintenance history

5.10 Energy Storage

If electricity transmission and steam distribution is the pipe between electricity and thermal energy production and building energy consumption, then energy storage can be the wide spot in the pipe. As a wide spot in the distribution of energy, energy storage essentially decouples energy production from energy demand. Energy storage allows the reduction of production capacity by shaving the peaks in instantaneous demand. In the end with energy storage, the amount of building energy consumption, in terms of kW-hours or BTUs, is not reduced, but the rate of production, in terms of kWs or BTUs per hour, can be reduced and load swings can be minimized. The result can be more efficient operation with energy production assets, delayed need for the addition of energy production capacity, and possibly the retirement of some energy production assets. However, recognizing that same energy is required for the end user, it must also be recognized that any energy storage process involves energy conversions which are not 100% efficient. There are energy losses in the conversion process. The measuring term used is “Round Trip Efficiency.”

Why is energy storage becoming important? The main reason is the advent of renewable energy production technologies, primarily wind and solar. Prior to the introduction of wind and solar energy production, the fossil fuel based electricity systems has functioned as a “just in time delivery” system. With a fossil fuel based electricity system, as load changes, production follows to serve it. As wind and solar production capacity increases, weather variability will cause increasingly abrupt changes to overall production capacity. It is believed that as the renewable portfolio exceeds 20% of total production capacity, energy storage as the method to dampen weather related variability will be required.

Today there are several energy storage technologies being used or explored. These are:

- Super Capacitors
- Flywheels
- Batteries – Lithium Ion, Zinc Bromine, Sodium Sulfur
- Compressed Air Energy Storage
- Hydrogen Storage and Generation with Fuel Cells and Electrolysis
- Pumped Hydro water storage
- Thermal Energy Storage

The technologies provide different round trip efficiencies, different durations of storage capacity, and have varying abilities to respond to load variations.

All of these technologies can provide forms of electrical energy storage. Thermal energy storage, however, is more commonly used for decoupling chilled water production from air conditioning cooling demand without electrical energy conversion.

Each technology is briefly described below.

Super Capacitors

Large electric capacitor banks store energy in the form of electrical charge. Through the size of the capacity banks, direct electrical current can be provided for seconds to a minute. Response to variable conditions can be immediate with this technology.

Flywheels

Flywheel energy storage systems utilize a heavy cylinder on a shaft that can spin rapidly, up to 22,000 rpm, in a vacuum within a robust enclosure. The cylinder shaft rides on magnetic levitation. The magnetic levitation and the vacuum in the enclosure combine to minimize friction-related losses and wear. The shaft is connected to a motor/generator. The motor/generator first acts as a motor to turn the cylinder, thereby converting electrical energy to kinetic energy. That kinetic energy is stored in the rotational momentum of the flywheel. The momentum, or stored (kinetic) energy, is converted back to electric energy when the motor/generator acts as a generator, imposing a load on the flywheel which slows its rotational speed.

Flywheel technology has been in development for eight years. Flywheels can provide minutes, up to an hour of electrical storage directly. Response to variable conditions can be immediate.

A unit by Beacon Power is shown in a cutaway illustration, and a 20 MW installation planed for New York.

Figure 5-9. Flywheel Energy Storage

Battery Storage

Battery storage is a mature technology and is commercially available. Batteries are generally an efficient means of energy storage, and are used extensively as a means of emergency back-up power for use when no other means is available, as is in the case for 24 Volt DC emergency power systems. Since batteries systems are direct-current, the power from them must either be used to energize DC systems, and may only be used to energize AC systems through a medium such as a M/G (motor generator) set or solid state inverter circuit. Battery storage can typically provide minutes, up to a couple hours of electrical storage directly. Response to variable conditions can be immediate.

In 2003, the world's largest rechargeable battery was constructed in Fairbanks, Alaska. Comprised of 13,760 NiCad cells, the $30 Million battery is able to provide 40 MW for a period of 7 minutes, and is used to provide uninterruptible power for the time that it takes to start up back-up diesel generators in the event of a blackout, or periods of grid instability which can be common in remote systems where there is a lack of reliable spinning reserve.

The following photograph is of a 2 MW battery system which can fit inside a shipping container.

Figure 5-10. Battery Energy Storage

Compressed Air Energy Storage (CAES)

Compressed Air Energy Storage is a technically viable means to store energy on a large scale. Typically large compressors store compressed air in a salt cavern where there is a surplus of electricity, and then when electric demand is high, the stored compressed air passes through a turbine generator. The compressed air needs to be heated, usually in several stages, as it is delivered to the turbine and between stages of the turbine. Heating may be with natural gas or with a waste heat if a source is available. The focus of compressed air energy storage is based solely on peak demand reduction, rather than a reduction of total energy use. Compressed air energy storage can provide hours of energy storage, and the amount is entirely dependant on the size of the cavern. Response to variable conditions is not immediate, and will take some time to start the system depending on its size.

The systems operation is based as follows:

- At night time, electric driven air compressors compress air into a storage volume (usually an underground void or cavern) Electricity used to operate the compressors may be purchased at a reduced rate during the off peak hours.
- During the day time, the compressors are shut off. Air from the storage volume is then expanded through an air turbine running a generator. Because some heat is lost during storage, the air is usually pre-heated with natural gas or some other heat source.
- The energy produced during the peak load period has a higher value, presumably, than the energy purchased off peak in its making, and overnight in its storage.

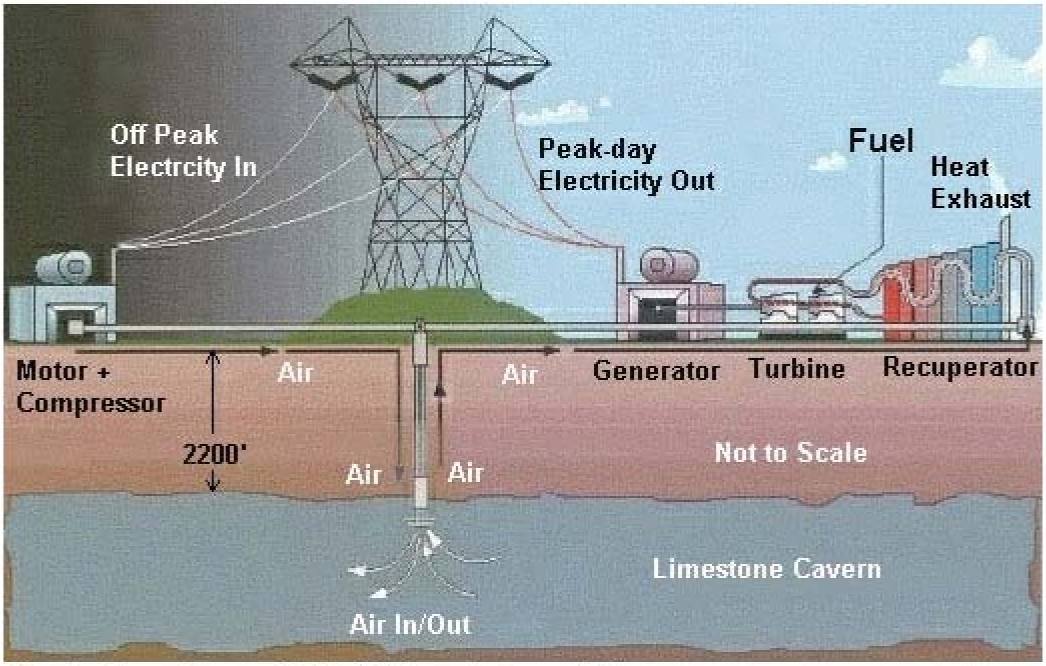


Photo Courtesy of CAES Development Company

Figure 5-11. Compressed Air Energy Storage

New York State Electric and Gas is working on a CAES project in a salt cavern in upstate New York.

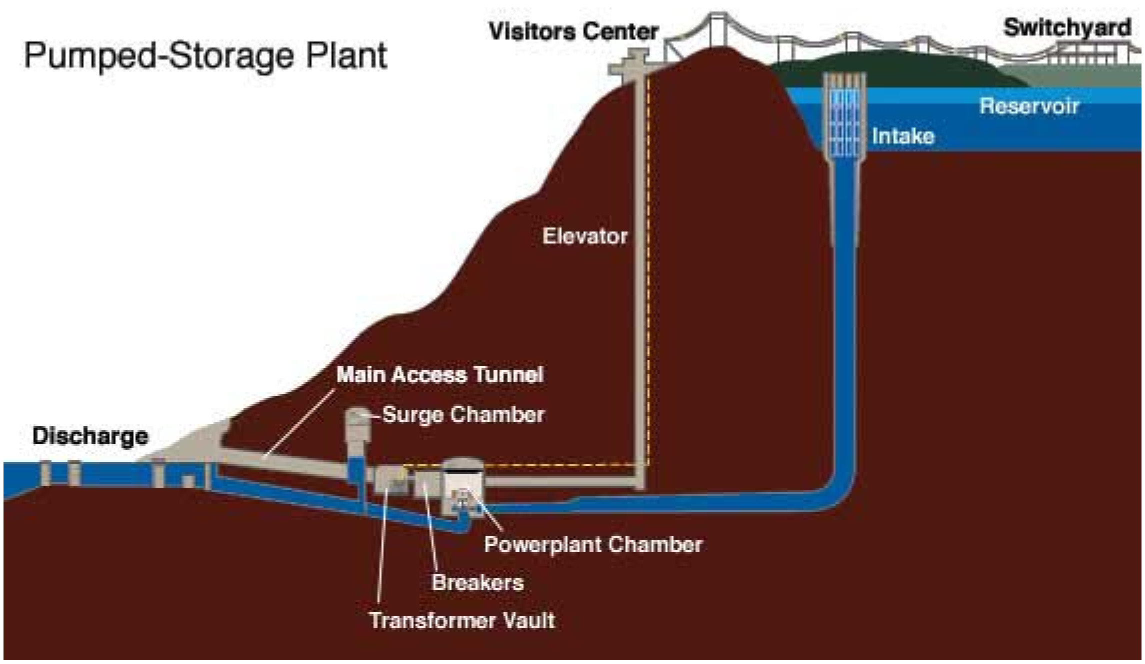
Hydrogen Storage

The most common present means of producing hydrogen is steam reformation of natural gas. The process produces both hydrogen gas and carbon dioxide gas. The amount of carbon dioxide gas that is produced is the same as would be produced from the natural gas in a standard combustion process. Hydrogen may also be formed by the electrolysis of water into hydrogen and oxygen. The overall efficiency of this process is low, and the value of hydrogen produced is much less than the electricity consumed in the process. High temperature electrolysis has the potential to increase efficiency, but it has not been accomplished at a commercial scale that is competitive with the cost of hydrogen that is simply produced from natural gas reformation. Also the high temperatures necessitate the use of special materials of construction.

As a storage medium the current technical, efficiency, and economic challenges associated with hydrogen storage make it a less advantageous choice compared to other storage processes like pumped hydro, thermal energy, and compressed air storage. However, the promise of hydrogen storage technology by some advocates is to use high efficiency electrolysis and fuel cells in a hydrogen cycle with renewable energy generation sources to provide a hydrogen cycle completely independent of fossil fuels. The stored hydrogen could even be used to power hydrogen fuel cell vehicles, as well as other heating purposes traditionally served by natural gas. The current state of the technology cannot fully deliver on the promises yet.

Pumped Hydro Water Storage

Pumped water storage is another means to shift demand. It combines a hydroelectric plant that converts energy from the elevation distance (static height) of a body of water to a lower discharge body during periods of peak demand. During periods of low demand water is pumped from the lower body, back up to the higher body of water. Two utility scale projects of this technology are the TVA owned Racoon Mountain Pumped Storage Plant near Chattanooga, Tennessee, and Consumers Energy Ludington facility in Ludington, Michigan. These plants have the capacity to generate up to 1600 megawatts of electricity. Pumped hydro can provide hours of electrical energy storage depending on the size of the smaller of the upper or lower reservoir. Response to variable conditions can be relatively fast.



Racoon Mountain Pumped-Storage Plant

Figure 5-12. Pumped Hydro Storage Diagram

Thermal Energy Storage (TES)

There are various ways to store thermal energy. In solar thermal power generation, it has been found that the integration of thermal energy storage in terms of a high specific heat salt can provide a more even production output as clouds pass overhead and for a controlled period of time at the end of the day. The system is described in section 5.8 above.

One more common way to employ thermal energy storage (TES) involves making ice or chilled water when energy prices are low so the cold that is stored can be used to reduce building cooling needs—especially compressor-refrigerant based cooling—when energy is expensive. Integration of TES into chilled water systems is described in section 7.2 below.

Energy Storage at MSU – Main reasons to consider energy storage technologies are:

- Operating costs related to the differential cost for peak power vs. off-peak. Since MSU produces most of its own electricity, there is no benefit.
- Avoided cost of capacity – If peak demand were to outstrip generating capacity, energy storage may be used as a means to avoid installing generating capacity, and perhaps other technologies such as chiller capacity, if the peak demands are the result of reaching cooling loads. This may be a benefit of TES to serve campus building expansions using existing chiller assets in lieu of new chillers.
- Grid stability - Following loads constantly places stress on central plant operations. So having additional stored energy can provide a means of smooth transitions to changing loads on the campus. This may become more important if large intermittent sources, such as solar photovoltaic and wind renewable generation are added to the generation base.

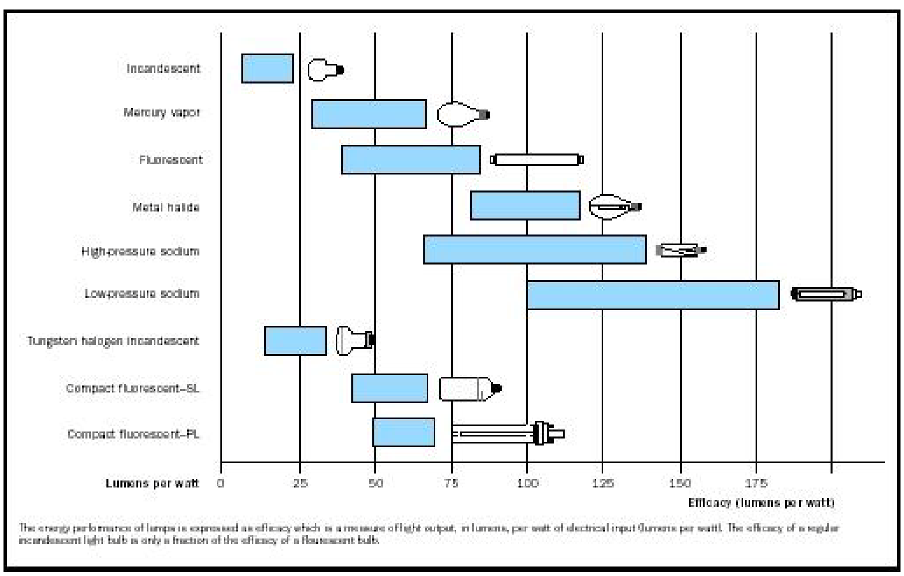
6.0 Demand Side Management/Smart Grid

6.1 Building Energy Systems

Buildings offer many types of opportunities, many of which are presently commercialized and may be implemented. These include building automation systems that optimize HVAC temperature and humidity set-points based on ambient temperature conditions, CO_2 demand based ventilation, lighting retrofits, and curtailment programs, and occupancy based lighting. Building energy consumption may be reduced by 10% to 15% on average by retro-commissioning existing systems and another 10% to 15% through energy conservation opportunities (ECO's), e.g. capital projects like exhaust air energy recovery, and other system upgrades. HVAC demand savings and lighting efficiency retrofits typically enjoy short payback periods. Rooms can be placed in comfort or stand-by mode depending on their occupancy schedule, availability of external ambient light, occupancy sensors, or external manual toggle through a network (i.e. smart grid). Some of these types of systems are already employed at MSU.

Lighting

Lighting upgrades usually rise to the very top of the Cost/Benefit evaluation. There are several kinds of upgrades that can be made with the objective of maintaining comfortable lighting levels, and color rendition, while reducing demand and usage of electricity. The efficiency of the lighting process, known as *efficacy* is measured in lumens per watt, and can vary widely among light sources.



www.pollutionissues.com/images/paz_01_img0081.jpg

Figure 6-1. Demand Side Impacts

Efficacy is only one parameter that changes with a lighting retrofit project. Each type of light source has a color rendering index (CRI) that rates the effect of a light source on the color appearance of objects on a scale from 0-100 points. In general the highest efficacy sources also have the lowest color rendition grade, with zero being the lowest quality of color rendition (low-pressure sodium lamps), and 100 being the highest (an incandescent or halogen bulb is a 100). Compact fluorescent bulbs have a CRI of 80, which is very good while emitting 2-3 times more lumens per watt over incandescent bulbs, making them an attractive candidate for re-lamping without the need for replacing fixtures. Finally, lighting levels should be appropriate for a given task. A parking lot typically requires (2) foot-candles; office space (50) and an operating room (1000).

Lighting improvements can be done in many ways but are generally categorized as one of the following:

- Replace incandescent bulbs with compact fluorescents (CFL's)
- Upgrade fluorescent fixtures with improved components
- Install lighting controls to minimize energy costs (e.g., curtailment)

One important lighting consideration is that it affects HVAC loads in interior spaces. Incandescent bulbs generate large amounts of heat in addition to their light output. This heat will go into the surrounding space and increase the overall cooling load during the summer, and decrease the overall heating load during the winter. When retro-fitting lighting equipment, these effects may raise or lower the total project savings depending on their specific application.

Table 6-1. Lighting Retrofits.

Capital Costs ($/kW)	Varies
Applicability to the Lansing, Michigan region	Applicable
Applicability for a university campus	Applicable
Readiness	Commercially available, mature technology

6.2 Chilled Water

The Campus has a very large array of chilled water assets which includes both electric and steam absorption chillers which are centralized, and some of which feed a district chilled water loop. The present trend in the University is to favor the installation of electric chillers for applications of 400 tons or less. The following table shows a list of the centralized chiller installations on the campus.

CENTRAL PLANT	CAPACITY in TONS	AREA SERVED in SQFT
Anthony/Engineering Addition 3	1,910	404,428
Bessey Hall	600	150,663
BPS/Biochemistry	3,750	534,952
Breslin Center	800	278,120
Engineering/Food Science/Natural Resources/Packaging/Comm. Arts	2,400	922,746
Fee Hall	1,000	388,071
Hannah Administration	730	170,215
International Center/Erickson Hall	1,600	346,567
South Kedzie/Marshall Hall	350	89,357
Kellogg Center	1,520	232,100
Library/Music Practice	1,800	493,122
Regional Chilled Water Plant #1	12,900	2,629,323
Union Building	652	208,924
Wells Hall	1,180	230,187
Total	31,192	7,078,775

Figure 6-2. Chilled Water Capacity

District chilled water plants are large energy users that have a highly variable load profile that reacts continuously to system demands for cooling. There number of strategies that may be employed to reduce both peak demand and increase plant efficiency to reduce overall usage. Typical strategies include:

- Thermal Energy Storage (TES)
- Free Cooling
- Chilled Water Reset
- Chiller Upgrades

Thermal Energy Storage (TES)

Thermal Energy Storage is a useful technology that is commonly used in central chilled water plants to “level the load”. There are two main forms of thermal energy storage systems for chilled water, ice systems, or stratified storage tank systems. It is likely that the stratified thermal storage tank is most promising for use at the MSU campus. The tank is essentially used as a reservoir for thermal energy which may be “charged” during times of reduced system demand, and then discharged during periods of high system demand.

Thermal Energy Storage at University of Texas Austin www.utexas.edu/.../thermal-energy-storage.jpg

Figure 6-3. Chilled Water Thermal Energy Storage Tank

The main economic benefit of the TES tank is that it reduces the demand profile, thus reducing the number of chillers needed to serve the load. The overall energy consumption of the facility remains the same.

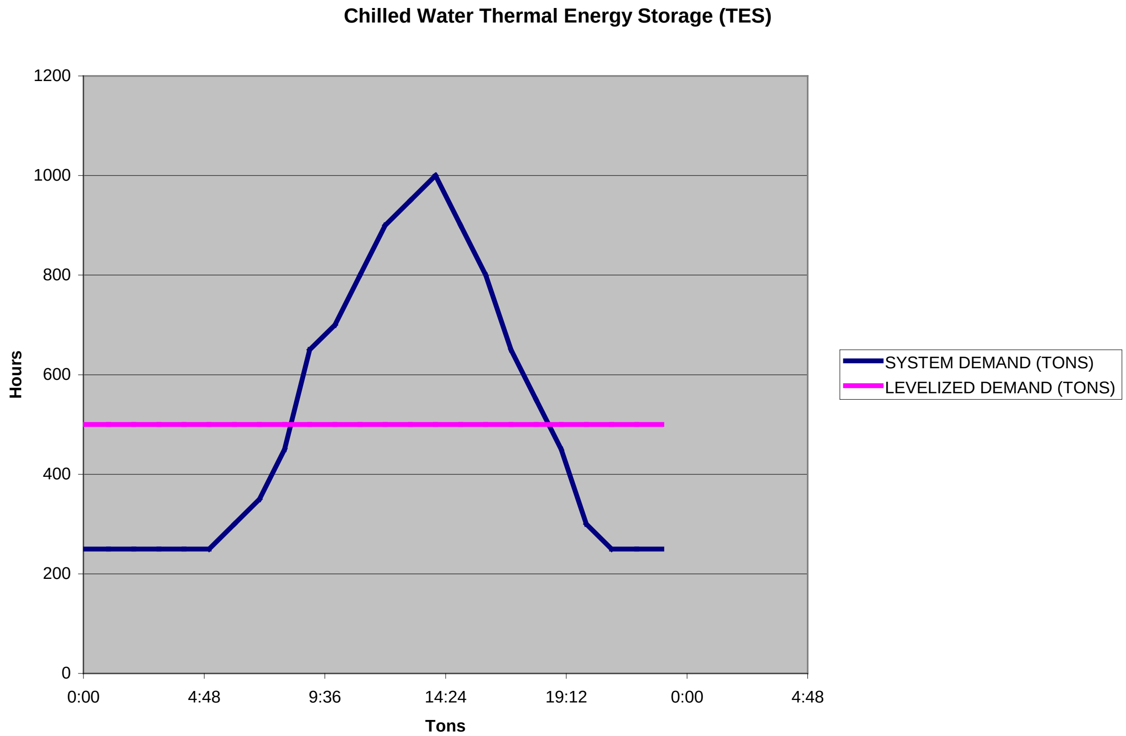
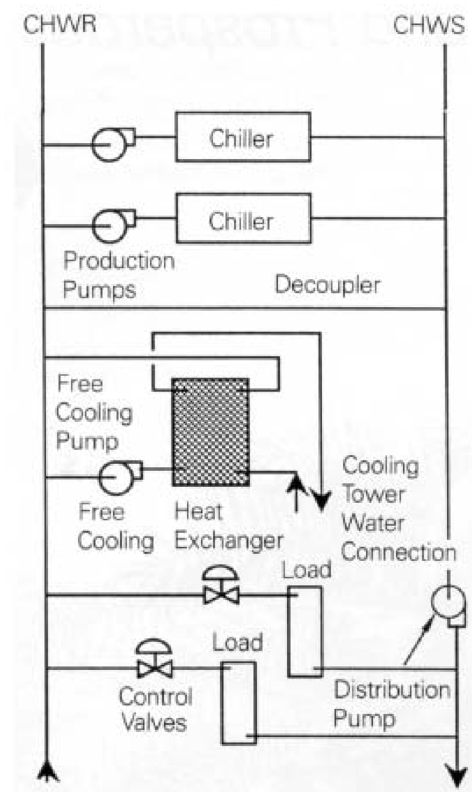


Figure 6-4. Chilled Water TES Load Shaving

As an added benefit to MSU, a TES tank could increase the effective capacity of existing systems to meet new campus demands without having to add chillers.

Free Cooling

Free cooling is a technology that is useful mainly in Northern climates like Michigan's. For chilled water systems involves using a heat exchanger to pre-cool the water returning to the central plant before it is processed with high energy use equipment (mechanical or steam absorption chillers). The heat exchanger may use water from a low temperature source like a lake or river, or evaporative cooling tower. The evaporative free cooling system is likely to be most applicable to the MSU campus. The energy consumption of the evaporative loop used to pre-cool the water is much lower than the cost to run the chiller; however, the evaporative loop requires low wet-bulb temperature ambient conditions that may not exist on high temperature days. This makes free cooling mainly an energy conservation measure, but not a peak load reduction measure. The combination of free cooling with thermal energy storage increases its effectiveness by allowing it to operate at a higher load during the evening when wet-bulb temperatures are at their lowest using the TES tank as a load. Free cooling complements TES.



Source: http://trane.net/commercial/library/en20-3.pdf

Figure 6-5. Typical "Side-Car" Free Cooling Arrangement

Chilled Water Reset

Chilled water reset is an operating strategy that is primarily applicable to centrifugal chillers. By raising the outlet set temperature of the chiller a degree or two when weather conditions permit (e.g. warm days, not hot days), the chiller does not have to work as hard. This results in significant energy savings at the central plant. In response to higher chilled water set points though, demand side equipment in the buildings like fan-coil units and air handling units may need to run longer, to maintain space conditions. In general the energy saved in the chillers exceeds the extra energy in the building systems. The added benefit to this strategy is that it produces higher return temperatures that can increase the potential effectiveness of free cooling systems as described in the previous section. Chilled water reset is best accomplished by automatically increasing the set-point in response to outside conditions. Care must be taken to avoid using this strategy for systems that may not tolerate the higher temperature conditions like laboratories or operating rooms. If such systems use a common chilled water loop, then they will drive the loop temperature for the other facilities as well, and may ultimately be better served with a dedicated system and thus allow the other facilities on the common loop to employ this strategy. Although chilled water reset is an efficiency strategy, and may also reduce demand, it is not likely to be useful as a strategy to reduce peak demand because the sizing of demand side coils will almost certainly require the low “design” chilled water temperature on the hottest “design” days in order to effectively cool the space.

Chiller Upgrades
Chiller manufacturers constantly refine their products to increase their efficiency. Electric centrifugal chillers used to boast of being able to achieve 1 kW/ton of refrigeration. The advent of enhanced capacity controls, and variable frequency drives has allowed efficiency to reach .6 kW per ton and lower. For steam absorption units utilizing double effect machines may increase efficiency by as much as 50% over single effect units.

The existing central chilled water assets and distribution systems increase the possibilities to employ these energy conservation measures at the MSU campus.

Table 6-2. Chilled Water Retrofit Technology Characteristics.

Capital Costs ($/kW)	Varies
Applicability to the Lansing, Michigan region	Applicable
Applicability for a university campus	High
Readiness	Commercially available, mature technology

6.3 Smart Meters

Present utility meters provide a very small amount of information to consumers. Smart meters are installations of sub meters that display and communicate demand and totalized usage enable the system operator to make decisions concerning energy use using real time data. Smart meters may also be configured to provide each facility with information from the central generating facilities such as cost for power, average lbs CO_2 / kwh based on the real time generating asset mix, and so make choices to defer or advance space conditioning operations depending on real-time operating conditions. In addition, sub metering enables cost centers to trend their energy use over time and compare it to metrics. The theory is that by giving the end user access to such information they will modify their consumption behavior to (presumably) reduce consumption, or shift consumption to off peak periods. Other possible uses are for a central facility observer to monitor and trend energy usage to a more granular level, and (presumably) identify above or below average energy consumption for some parts of the system, or to identify curtailment opportunities in the case that generating assets are not available.

Facilities can be given an energy consumption target for steam use and electricity use and use the smart meters to quantify the effectiveness of energy conservation measures. The savings demonstrated in this way might be banked for other new projects within the cost center.

Smart Meters are an evolving technology. While sub-metering systems that can enable reading electricity demand and usage are available, ones which communicate advanced information from and to a central control system on a real-time basis through existing communication systems do not appear to be standardized. A key challenge for optimizing energy use at MSU may be in finding submeters that meet the simple needs to support overall measurement and verification needs for energy conservation programs, while still being able to be integrated into a centralized system with information exchange that is relevant to MSU's needs. It should be noted that the cost of production for on-peak vs. off-peak at MSU is likely to be very marginal, and not relevant to user decisions, so that may not be a tangible benefit of smart meters for MSU, whereas identifying the availability of wind generation or renewable % kWh could be more applicable. Such metering equipment is not well standardized or available at this time.

Table 6-3. Sub/Smart Meter Technology Characteristics.

Capital Costs ($/kW)	Little data available
Applicability to the Lansing, Michigan region	Average
Applicability for a university campus	High (For Sub-meters) Average for Smart-Meters
Readiness	Commercially available, mature technology for sub-meters, immature for Smart-meters

6.4 Smart Grid

A "Smart Grid" is a power generation, transmission, distribution, and user network providing both:

- the reliable delivery of power from generators to users, and
- two-way communication among all entities involved in the power grid.

First, the typical campus power distribution system may be as shown in the figure below.

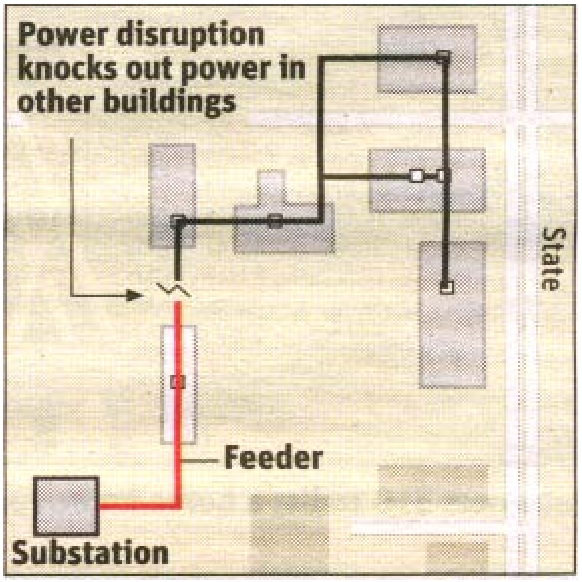


Figure 6-6. Typical Campus Power Distribution

Reliability is enhanced through a distribution loop providing two sources of power to every user, as shown on the next figure.

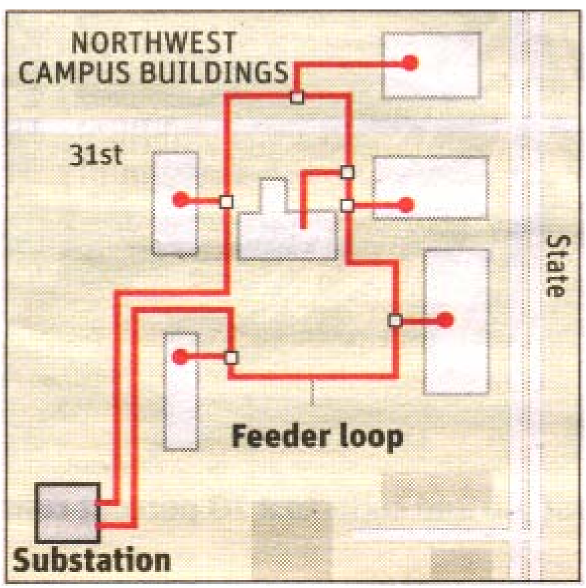


Figure 6-7. Looped Campus Power Distribution

Then the looped power transmission and distribution has added to it a highly reliable telecommunications network of meters and controllers. Through this network, the Smart Grid integrates large, centralized generating units and small distributed generating units. It integrates conventional generating units and renewable energy systems such as solar and wind. It integrates all of production and all users into an overall structure which communicates real time demand and production allowing central or distributed control of production output and user demand to balance and optimize the efficient operation of both. Through the integration of generators and users in a two-way communications network, the Smart Grid can alarm any abnormalities or interruptions in the network, pinpointing the location of the problem instantly. Advanced sensors, meters, and controllers that enable remote control and automation, and a decentralized two-way communications network transmitting real time information and control commands, are much of what makes this possible.

The Smart Grid has the potential to facilitate demand side management (DSM) strategies such as curtailments, and load leveling in order to reduce peak loads. The advanced sensors, meters, and controllers on the demand side provide for two-way communication through the Smart Grid network. Through them, a power generator will be able to send instructions back through the meters to control home appliances, like a cooling thermostat that can be adjusted remotely a few degrees upward on a hot day during peak demand periods to reduce the power demand from the air conditioner, and avoid a brownout in the community. At peak demand times the power generator, through the Smart Grid, could alternate the operation of some equipment, such as DX air conditioners, to reduce electricity demand, or it could turn off chillers and discharge chilled water from a thermal energy storage (TES) tank. Later, when demand decreases, a Smart Grid could turn on the DX air conditioners. Also at low demand periods, the Smart Grid could also start enough chillers to both provide cooling to meet current demand and provide additional cooling to charge the TES tank in preparation for the next day's peak power demand.

Another critical aspect of the Smart Grid system is that it allows end consumers to actively participate in the energy market and thus make a contribution to climate protection, as well as saving money. It is likely that the Smart Grid will change consumer behavior as they monitor energy consumption numbers with their costs and consciously turn users off, or if they have the choice, allow the Smart Grid to power them down during times of peak rates. This may be accomplished through the use of smart meters that communicate instantaneous information about consumer demand, and cost for power. By providing this information to each cost center, they will be armed to make decisions about energy use, and potentially provide local incentive for load curtailment by allowing energy cost savings to remain in the cost center.

Another major argument in favor of the Smart Grid is that it can control both the supply and the demand side of the equation to enable more efficient electricity production and lower demand peaks. Lower demand peaks coupled with the integration of distributed generation sources on the supply side may delay the need for the building of additional central plant generating units and reduce loads on overburdened distribution systems, and it may reduce the need for peaking plants to be started. Peaking plants are generally simple cycle combustion turbine generators that have a low capital and high operating costs, but only operate to serve peak demand when existing base loaded capacity such as coal fired and nuclear units are fully loaded. Because MSU has sufficient installed generating capacity to meet all of its near term needs, the benefits of the Smart Grid are that it may delay future expansions which otherwise may have been needed to serve peak demand. Another benefit is that it may favor larger scale installation of other generating sources like wind or solar that have less of a carbon footprint, but have intermittent availability, that left unmanaged might threaten the stability and power quality of the distribution system, and also force load swings on the other generation assets. By using the smart-grid, demand changes and power surges can be actively managed to favor renewable generators and reduce load swings. In this case, the benefits are increased stability, reduced fossil fuel use, increased utilization availability of renewable energy sources that generating plant cycling is reduced, efficiency is increased, and therefore reduced pollution is reduced. Now, if some of the existing boiler assets are converted to a renewable fuel source, there is likely to be an accompanying derate or a loss of steam generating capacity of 50% or more. In this case the ability to reduce peak loads becomes more critical because of the associated reduction in generating capacity.

Through these functions the Smart Grid can increase the efficiency, reliability, and security of the power supply chain while reducing carbon emissions.

If the sun is shining and the solar PV systems are generating at peak output, then electric chillers will be automatically run to both serve the load and charge the TES tanks taking advantage of the surplus of renewable energy sourced electricity. If the day is cloudy and solar PV is generating very little electricity, the TES tanks will automatically supply a portion of the chilled water to meet the cooling demand during the heat of the day allowing some of the chillers to shut down decreasing electricity demand during peak demand hours.

University Cases

Illinois Institute of Technology and the University of Illinois are leading statewide public-private partnership called the Illinois Smart Grid Collaboration whose purpose it is to speed the adoption of a smart grid in the state of Illinois.

The Collaboration has four primary components:

1. The Illinois Institute of Technology Perfect Power System: A complete, replicable, and scalable demonstration of a “never-fail” Smart Grid that would eliminate blackouts and make our energy cleaner, more secure and more efficient.

2. The Oak Park Community Demonstration: A demonstration of the technological, financial and policy investments communities can make right now, in coordination with their utilities, to leverage Smart Grid Advanced Metering Infrastructure (Smart Meter) investments to achieve cheaper, more efficient, and more reliable energy in homes and businesses. The demonstration will begin with Oak Park, Illinois and expand to other communities.

3. The Illinois Institute of Technology Smart Grid Demonstration Center: A comprehensive technology development, demonstration, and evaluation platform for Smart Grid technologies that will allow companies to "plug-in" to an existing Smart Grid (IIT's Perfect Power System) to speed the development of their new Smart Grid technologies and products.

4. The University of Illinois Smart Grid Validation Facility: An incubator, laboratory and advanced test bed that will allow companies to validate their smart grid technologies to ensure they are used in trustworthy configurations that meet cyber security and interoperability standards before they are implemented on the grid.

The University of California – San Diego (UCSD) is creating a 42 MW microgrid that self generates 80% of its combined heat and power (CHP) requirements. The school is embarking on a supply/storage/demand optimization project that is acting as a living laboratory for the early introduction of quantum advancements in smart grid technologies. The ultimate goal is to concurrently reduce the campus' energy costs and carbon footprint by integrating PV, fuel cells and biogas resources with its thermal and electricity storage infrastructure which will occur in parallel with a funded $72M, three year energy efficiency program to reduce its total demand, particularly on peak demand. The California Energy Commission, California Public Utilities Commission (CPUC), utility, SDG&E and Department of Energy (DOE) is co-funding the laboratory.

Here are some quick facts on the project, starting with some information on UCSD:

- With a daily population of over 45,000, UC San Diego is the size and complexity of a small city

- As a research and medical institution, it has two times the energy density of commercial buildings

- UCSD has 11 million square feet of buildings and $250M/yr of building growth

- It self generates 80% of its annual demand

To date, the university has completed $60M in energy retrofits reducing energy use by 20% or 50M kWh/yr, saving UCSD $12M annually. It has a high voltage substation, thermal energy storage, co-generation, topping steam turbine and operates on digital controls. It also employs a comprehensive metering system with electric and thermal interval meters reporting to a central database.

Its demand response program is robust and includes:

- A Capacity Bidding Program (participates in a day-of program)

- A shut down of electric chilling (or increases generation if available) through its central plant

- Automatic control of MetaSysNon-critical room temperature setpoints

- Voluntary conservation (whereas the campus community is asked to shutdown all non-critical electrical devices)

In addition, the university has a strong energy efficiency initiative and is deploying solar power (1MW of PV energy) along with fuel cells (a 2.8 megawatt methane powered fuel cell).

UCSD also believes the missing link is enabling technology in energy storage and is pursuing four energy storage projects including:

- Distributed Energy Storage

- Frequency Regulation

- Optimized Thermal Energy Storage

- Grid to Vehicle Integration

The university is banking on all of these combined initiatives to create a smart microgrid that is nationally replicable and scalable. But for now the massive undertaking is truly a living laboratory that anyone in the energy business can admire in addition to looking forward to the results this project will offer.

Table 6-4. Smart Grid Technology Characteristics.

Capital Costs ($/kW)	Unknown
Applicability to the Lansing, Michigan region	Applicable
Applicability for a university campus	Applicable
Readiness	Commercially Available

For Michigan State University:

Applying two-way communications and control requires an assessment of critical and non-critical loads. Critical loads would be defined as loads which do not allow remote starting and stopping, while non-critical loads could allow remote starting and stopping. Non-critical energy users which may be controlled remotely might include:

- DX air conditioners
- Clothes washers
- Air compressors
- Snow melting
- Chillers

Critical energy users which may not be controlled on a two-way basis might include:

- Medical facilities
- Server Rooms
- Chillers
- Research facilities

Systems which may be utilized or added to enhance supply side flexibility might include:

- Emergency Diesel Generators
- TES
- Plug-in hybrid and electric vehicles charging centers

Existing Distributed Generation Capacity which may be monitored and controlled currently includes:

- Solar PV

Possible future distributed generation technologies might include:

- Micro Turbines
- Fuel Cells
- Wind
- Hydro

7.0 Selection of Options

This section evaluates technology options for the following:

- Technical maturity: prioritize options on the basis of technical maturity and commercial availability
- East Lansing campus applicability: Screen out options which are not applicable to the East Lansing climate or the University campus
- Prioritize technology options on the basis of MSU's evaluation criteria.

Technical maturity may be categorized and then prioritized according to the following:

- mature technology with operational and maintenance history, commercially available
- new but full scale installed technology with short operating history, commercially available but with risk
- tested technology with reduced scale operational results, limited scale development availability
- development technology with laboratory measured results
- conceptual technology with theoretical results
- emerging technology seeking development funding

For developing technologies, identification of time frames for commercially availability is recommended. For technologies not applicable to East Lansing climate or campus conditions, initial screening is recommended.

The following is a sample flow chart for an energy project screening process that may be used employed by MSU.

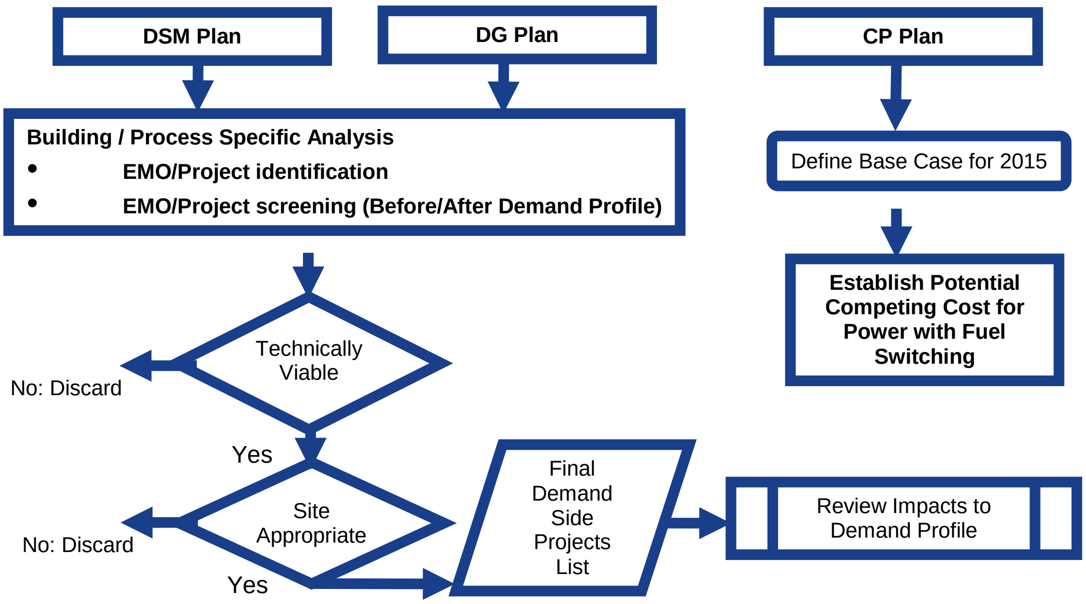


Figure 7-1. Flow Chart

Matrix

Michigan State University Campus Energy Strategy

30-Nov-10

Attributes		Measures	Option s									
			Photovoltaic (PV) utility-scale[1]	Photovoltaic (PV) rooftop[1]	Wind[1]	Small Scale Nuclear Reactor[2]	Certified Renewable Grid Portfolio[1, 3]	Coal (with CCS)	Coal (without CCS)	Natural Gas	Biomass Co-firing	Energy Efficiency and Retro-Commissioning
Objectives												
Capital Cost	Start-up Cost (one-time expense, T1)	U.S. Dollars / kW installed capacity	\$4,000/kW installed capacity	\$5,000/kW installed capacity	\$2,525/kW installed capacity for utility scale farm, significantly more (perhaps double) for single turbine.	>\$11,000/kW installed capacity[4]	Ownership share would require negotiations with developers in region	>\$9,000/net kW installed capacity	\$3,800/net kW installed capacity	\$1,200/net kW installed capacity[5]	\$600 to \$1400/net kW installed capacity[6]	Varies [7]
Operating Cost	Annual operating costs, less revenue generated (T2…TN)	U.S. Dollars / kW installed capacity per year	\$19/kW installed capacity per year[8]	\$38/kW installed capacity per year[8]	\$40/kW installed capacity per year[8]	\$265/kW installed capacity per year[9]	\$0.114/kWh as levelized cost of energy (LCOE)	\$860/net kW installed capacity per year[10]	\$320/net kW installed capacity per year[10]	\$330/net kW installed capacity per year[11]	\$770/net kW installed capacity per year[12]	Cost savings are generally needed to justify any efficiency project
Employment	Additional employees at Michigan State	Number of new employees (FTE=1, Part-time=0.5)	1 person / MW installed capacity[13]	1 person / MW installed capacity - might take several rooftops to get to 1 MW	0.2 people / MW installed capacity	20 operators additional plus 3 added Security Staff at central plant	Unlikely to need any if not in managing partner position	12 operators additional at existing central plant[14]	4 operators additional at existing central plant[14]	None additional at existing central plant[14]	6 operators additional at existing central plant[14]	None additional
Student Employment	Additional student employees at Michigan State	Number of student employees / year (assuming 10 hr / week appointment)	1 - for annual module cleaning	1 - for annual module cleaning	Possibly as apprentice role	5	Unlikely to need any	Likely none additional[15]	Likely none additional[15]	Likely none additional[15]	Likely none additional[15]	Unlikely to need any
Carbon Emissions	Annual carbon emissions	tons CO_2 / MW year	Zero, post installation	Zero, post installation	Zero, post installation	Zero	Should be full offset of CO_2, but total depends on MWhrs of production resulting from share purchase	Zero[16]	20,000 tons CO_2 emitted/MW year generated	11,000 tons CO_2 emitted/MW year generated	Zero net CO_2 production (biomass is renewable)	Generally a 5% or more reduction in energy consumption (and associated emissions) for each building.
Land use impacts	Land displaced by energy production infrastructure in Michigan	Square feet / kW	261 square feet/kW installed capacity	390 square feet/kW installed capacity[17]	2700 square feet average/kW installed capacity[18]	0.5 acre footprint for power only, does not include parking Power Island	Zero on campus	About 10 square feet per net kW installed capacity includes fuel storage	About 3 square feet per net kW installed capacity includes fuel storage	< 1 square foot / net kW	About 12 square feet per net kW, includes fuel storage.	Zero for compact fluorescent lighting, HVAC, & controls retrofit, to 0.25 acre per chilled water TES tank.
Environmental (Air Quality)	Public health as measured by SOx and NOx emissions	tons SOx & NOx /MW year	Zero, post installation	Zero, post installation	Zero, post installation	Zero	Depends on mix of technologies, biomass would have SOx and NOx emissions for instance	0.7 NOx and 5.6 SO_2 assuming 90% capture efficiency	4.0 NOx and 32 SO_2	2.7 NOx and <0.2 SO_2 Depending on sulfur content in fuel	2.8 NOx and <0.2 SO_2 For CFB with SCR	Generally a 5% or more reduction in energy consumption (and associated emissions) for each building.
Leadership / innovation	Benchmarking with peer institutions (ranked by third-party experts)	1 = No innovation 10 = High innovation	1 likely, but depends on PV technology chosen[19]	1 likely, but depends on PV technology chosen[19]	3	10	1	10	1	1	7	5
Educational opportunities	Research projects, class assignments / projects related to power production at Michigan State	Yes / No	Yes, with monitoring of equipment, possibly work related to PV production modeling vs. actual looking at differences due to degradation, snow cover, soiling, etc. for various technologies	Yes, with monitoring of equipment, possibly work related to PV production modeling vs. actual looking at differences due to degradation, snow cover, soiling, etc. for various technologies	Possible with apprentice role and monitoring	Yes	Unlikely, but might gain access to production data, although developers might be reluctant to share publicly.	Yes	Yes	Yes	Yes	Yes
Limiting Factor[20]	Ratio of what can be installed vs. current capacity	Percent	20%	20%	20%	100%	50%	100%	100%	100%	30%	Not Applicable
Capacity Basis			1MW to 100MW	100 kW to 1MW	Multiple 1 MW turbine utility scale wind farm.	25 MW Net	Varies	40 MW Net	70 MW Net	12.5 MW Net	100 MW Net	Varies
Capacity Factor [21]	Measure of the average actual unit output capacity vs. installed nameplate capacity	Percent	12% or less	12% or less	25% - 35%	95%	100%	50% - 95% (Lower factor expected during the first years of operation and progression to high availability during later years as new controls & technology issues are worked out)	90% - 95%	95% or greater	90% - 95%	100% for lighting retrofits and possibly lower for curtailment based systems

Foot Notes

1 Option lacks thermal component to power generation therefore requiring additional steam generation to serve campus thermal loads.
2 Current SMR reactor concepts in US NRC pre-application discussions, include: Westinghouse's IRIS, NuScale Power Inc.'s NuScale, PBMR Ltd's PBMR, Toshiba's 4S, Hyperion Power Generation's Hyperion, GE Hitachi's PRISM, and B&W's mPower.
These technologies are approximately 10 years from being commercially available. It is recommended that the University revisit the status of commercialization in five years.
3 Only certified (the source) renewable energy, purchased from the grid.
4 First of a kind engineering (FOAKE) installation. Cost is expected to be lower after several of the small modular nuclear have been built and operated.
5 \$1200/kW cost includes combustion turbine and heat recovery steam generator installed cost. Additional Owner costs for building, tie-ins and other site specific costs are likely to add significantly to the overall project cost for a CHP plant.
6 \$1400/kW cost is applicable to co-firing existing coal boilers at small percentages, mostly material handling and AQCS work. A new stand alone 100 MW condensing cycle generating unit burning only biomass would cost up to \$4,000/kW.
7 Capital costs for energy efficiency projects are highly variable. There are a range of technologies where savings are high relative to costs. Generally lighting efficiency projects and HVAC controls upgrades, including curtailment based savings offer the best payback periods of 3-5 years.
Central plant retrofits and upgrades to capital equipment such as high efficiency chillers and Thermal Energy Storage (TES) are more expensive and usually have a much longer payback period unless they are used to avoid capital expansion of generating assets as well as energy usage.
8 Production estimate needed to determine expected operating cost. Estimated values are with 30% accuracy.
9 Fuel and Non-Fuel O&M costs for First of a kind engineering (FOAKE) installation. Cost is expected to be lower after several of the small modular nuclear have been built and operated.
10 Cost assumes coal price is \$50/ton, and includes cost to purchase limestone & water and cost of handling ash.
11 Cost assumes natural gas price is \$9.00 per MMBtu
12 Cost assumes biomass price is \$24/ton, and includes cost to purchase limestone & water and cost of handling ash.
13 Pennsylvania AEPS Report
14 New employees are based on the assumption that new coal, biomass, or natural gas capacity will be built at the site of the existing power house and use existing staff
15 With the assumption that new coal, biomass, or natural gas capacity will be at the site of the existing power house, it is likely that current student employment would be unchanged.
16 Value assumes 100% capture efficiency and 100% containment integrity for ever.
17 Due to roof vents and other unusable areas, gross roof space will be higher as suggested.
18 Acreage required for wind is dependant on several factors including tower height, arrangement of towers, size of generators, and expected wind speed.
19 1 Not innovative - a-Si/amorphous silicon, polycrystalline flat plate
5 Somewhat innovative - Sharp multi-junction a-Si/micro crystalline, Sanyo HIT multi junction. Most higher (20%) efficiency single crystalline
10 Very innovative - Solyndra CIGS "rods" for rooftop, any CIGS flat-plate module, RF Micro Devices GaAs cells (not even out yet, but good candidate for limited space/rooftop applications), most products with cells built into the roofing material
(Derbisolar-yes, but Uni-Solar PVL is older), any new racking system w/o roof penetrations or heavy ballasts (Solyndra product allows these methods), some covered parking applications with innovative panels and/or EV charging stations built in.
20 Limiting Factor is the ratio of the capacity which can be installed vs. current installed capacity. The limit may be due to grid stability as for solar PV and wind power or due to existing boiler limitations as for biomass.
21 Capacity Factor is the ratio of output over time vs. installed capacity. A unit that is experiencing an outage, or one that does not have sufficient fuel (or wind, or sunlight) for conversion to electricity will have lower capacity factors than one that does.
Low capacity factors increase the overall cost of energy on a per kWh basis because there are fewer kilowatt-hours available to bill cost recovery for the equipment.

Energy Transition Outreach: What's the Community's Temperature?

Introduction

In 2011, a diverse steering committee of students, faculty and staff was formed to write an Energy Transition Plan. This plan creates the framework to transition the campus to renewable energy. The community was invited to engage in the process in three different ways:

1) **Energy Portfolio Modeling Sessions**: In-person facilitated events in computer labs on-campus (April-October 2011)
2) **Energy Transition Town Hall Meetings**: In-person facilitated events held in meeting spaces on- and off-campus (September-October 2011)
3) **Online feedback forms and comment forms**: Either on-line or hand-written feedback (14 responses) (January-October 2011)

The Energy Transition Outreach process had a vision to sustain open routes of communication among all participants as a way to keep constant and open feedback.

Various mediums were and still are being used to solicit feedback, engage conversation, and inform:

- Energy Transition Plan website (energytransition.msu.edu)
- Be Spartan Green website (bespartangreen.msu.edu)
- Be Spartan Green Facebook page
- Be Spartan Green Twitter
- Be Spartan Green E-newsletter
- Be Spartan Green Listserv
- MSU News Stories
- Press Releases (see Appendix VI: Articles published about the MSU Energy Transition Plan)
- Presentations to local organizations, including:
    - Lansing Can Do Better
    - Mid-Michigan Environmental Action Council
    - Michigan Energy Options
    - Michigan Environmental Council
- Deans, Directors, and Chairs listserv (DDC list)
- State News advertisements

Sample Size

The population of the study consisted of any willing and able MSU community members.

An open invitation method for soliciting participants was utilized to invite those interested participants to participate in the ten energy modeling sessions and seven Town Hall Meetings in 2011.

The MSU community is further defined as six stakeholder groups:

- Students
- Faculty /Staff
- Administration
- Alumni
- East Lansing area community members

Graphs that demonstrate sample sizes for each stakeholder groups for the three different data sets are provided in Appendix II. Appendix III contains the desired sample size for a confident statistical sample and the population of each stakeholder group. To summarize:

1) **Energy Portfolio Modeling Sessions** (110 participants)
2) **Energy Transition Town Hall Meetings** (157 participants)
3) **Online feedback forms and comment forms** (14 responses)

Energy Portfolio Modeling Sessions

Over the course of 2011 there were ten modeling sessions hosted at various locations and at different times of the day in order to attract a diverse audience. Participants were asked to make an energy profile for MSU, the requirements of which were to meet the estimated electrical and steam demand. In subsequent steps, they compared their scenario to:

- The 'Current scenario': a best attempt to capture "business as usual"
- Alternative 1: a relatively low-cost option that focuses on fuel switching and utilizing existing equipment
- Alternative 2: a radically different alternative that focuses on distributed generation and renewable energy sources

Overall, participants (regardless of demographics) preferred Alternative 2 compared to their scenario, showing a preference toward renewable energy.

Then participants were asked to rank the importance of performance indicators – student fees, GHG, air emissions, innovation, jobs and land use. General or direct ranking of the modeling session results and swing weighting results indicate relative importance of each of the six different performance indicators. Based on the median response, the rank order of criteria overall is approximately as follows: 1=Student Fees; 1=GHG; 1-Air Emissions; 4=Innovation; 4=Jobs; 6-Land Use. Both of the weighting techniques [1] found a preferred rank order for the three reference alternatives.

E-mail and Feedback Forms

The MSU community was encouraged to submit e-mail feedback and comment forms, which were available online at energytransition.msu.edu and in person at the Town Hall Meetings. In all, 14 responses were submitted, most from community, alumni, and students.

Energy Transition Town Hall Meetings

Beginning in September 2011, there were five Town Hall Meetings and two meetings with the Residence Hall Association and the Associated Students of Michigan State University in order to receive community feedback on the draft Energy Transition Plan goals and strategies. *Table 1* shows the times, dates and number of attendees to the meetings.

[1] Direct Ranks: reveal the 'gut reaction' to an alternative; whereas the Swing Ranks (inferred from Swing Weights): reveal which alternative 'best' perform on the most important criteria, as defined by the users.

Table 1: Summary of Attendance at the Town Hall Meetings

Date of Town Hall Meeting	Number of Attendees
September 13, 2011	23
September 21, 2011	13
September 29, 2011	25
October 5, 2011	9
October 19, 2011	19
November 2, 2011	42
November 3, 2011	35

Topics of Feedback

There were 27 topics (See *Appendix IV*) identified from feedback, received from town hall meetings and written comments. Some Energy Transition Steering Committee and Outreach team members attended these meeting, but their comments are not included in the analysis. *Table 2* summarizes the number of key themes each stakeholder group discussed throughout the seven Town Hall Meetings (THM)[2].

Table 2: Topics Discussed by Stakeholder Group

Population Group	Topics mentioned/all topics
Administration	**4**/27
Alumni	**3**/27
Community	**13**/27
Faculty/Staff (F/S)	**22**/27
Student	**24**/27

Of the 27 topics, the most frequent topic categories were: 1) institutional suggestions, 2) infrastructure suggestions, and 3) transparency.

[2] THM=Town Hall Meeting

Institutional[3] Suggestions

Institutional suggestions were the most common topic for all five stakeholder groups. This topic refers to comments made by any of the participants that are suggestions to include in the energy. Frequently referenced INS ideas included:

- *Create % coal reduction goal (S-THM)*
- *X boiler retired in year Y (S-THM)*
- *Create energy efficiency goal (F/S-THM)*
- *Create finance scheme to pay for renewable energy and broader sustainability projects on campus (S-THM, F/S THM, Alumni THM)*
- *Costs of strategies (F/S-THM)*
- *Broad collaboration with diverse entities (i.e. decision makers, politicians, NGO, government offices etc.) (S-THM, COM-THM, Alumni-THM)*
- *Compare our plan to other power producing entities using generally accepted bench-markers (COM-ER4, F/S-THM, S-THM)*
- *Visibility of energy projects to greater community to promote buy-in, awareness and commitment level (F/S-THM, ADMIN-THM)*
- *Insert MSU into the local policy context (S-THM, F/S-THM, Alumni-THM)*
- *Incremental steps (S-THM, F/S-THM)*
- *Include transportation emissions into emission calculations on campus (F/S-TWM, Alumni-THM, COM-THM)*
- *Research (COM-ER, S-THM)*

Community members were concerned about MSU setting an example as a leader in clean energy production. For example, one e-mail response from a community member suggested:

> *"…it's time for MSU and all of Michigan to step up to the plate and provide LEADERSHIP in transitioning to sustainable, clean forms of energy production. Please don't be a part of the problem, be a part of the solution for our future generations, many of whom will be students at MSU."* (Com-ER 11-4-11).

Some community responses in this category related to MSU demonstrating leadership by closing the power plant. For example:

> "*I urge you to show some leadership and demonstrate that Michigan State is truly Spartan Green. Commit to shutting down the T.B. Simon coal plant and announce a timeline to transition Michigan State University to 100% clean energy in your students' lifetimes, Thank you*" (COM-ER 11-1-11)

> "*MSU's T.B. Simon dirty coal plant is exposing thousands of students to toxic emissions every day. To demonstrate that Michigan State is truly Spartan Green you should commit to shutting down the Simon dirty coal plant or, if possible, convert it to natural gas*" (COM-ER 10-31-11).

Students' feedback included that the energy plan needs to be "*aggressively detailed*" (Student-THM 9-21-11 pg 4), commenting that both the emission reduction goals and renewable energy goals were not innovative enough

[3] Institution= Refers to customs (verbal and non-verbal) and behavior patterns important to a society/community with a common social purpose
[4] ER = E-mail Response

for them. During town hall meetings students explicitly stated that they want to have the retirement of the power plant apart of the plan.

Faculty/staff comments were directed toward the feasibility of executing the draft goals. A staff member during the last town hall meeting suggested that:

> "*…for the emissions goals there is a way to achieve that, but the renewable part that is very aggressive*" (Staff-THM 10-19-11 pg 10).

Maintainability of an energy plan was an idea specific to the staff during the town hall meeting. A staff member suggested that:

> "*If you don't maintain the change, the efficiency; then the paradigm shift doesn't matter in ten to fifteen years because you will be having this same conversation over again. So maintainability along with sustainability is a huge part*" (Staff 10-05-11 THM pg 9).

A faculty member during the final town hall meeting commented on the inherit assumption of the plan that population will increase and that campus will continue to build more infrastructure:

> *"So maybe our campus is going to shrink in the future because we will have other ways to learn and discover* (Faculty 10-19-11 THM pg 14).

Over all, the five stakeholder groups commonly stressed the importance of integrating a sociological element into the plan to raise general awareness through education and behavior changes and more importantly adopt the next step which is to increase the commitment level among all stakeholders in the greater East Lansing and Lansing communities.

Infrastructure Suggestions

Infrastructure suggestions were the second most talked about comments by all five stakeholder groups. For the purpose of this project IS was used to define ideas, comments or suggestions in favor of an alternative technology or idea that is believed to be currently available to add the campus infrastructure and help MSU achieve the 100% renewable vision. Frequently referred to IS suggestions included:

- *Incorporate more renewable energy technologies onto MSUs campus (S-THM, F/S-THM, F/S-ER, COM-ER)*
- *Don't waste assets that have value (COM-THM, F/S-THM)*
- *Install electric meters on buildings (COM-THM, S-THM)*

Some unique suggestions for infrastructure came out in the THMs. Students suggestions included small modular incinerators and green roofs. Faculty and staff suggestions included the energy load shifting where on-peak energy use is shifted to off-peak periods and thermal mapping of campus to locate energy leaks. This is an example of a suggestion from a faculty/staff person:

> *"I think there should be an attempt to think deeply about how you {the implementation team} encourage efficiency but capture the use of renewables on a personal scale as opposed to {a} grid connection*" (Faculty-THM 10-19-11 pg 15).

A further element suggested for next steps came from a faculty member during the last town hall meeting. The suggestion was to align the university's purchasing with the broader sustainability visions of the institution.

"*If you want to take on another element of this as far as a green university goes, how are we utilizing our financial assets and how are the endowments used to reflect our values of a green institution to reflect these goals*" (Faculty-THM 10-19-11 pg 15).

Transparency

Transparency (TS) was used to code specific comments and/or questions that are made regarding how a committee process is executed and/or how the participation of public will be taken into account at any point in the energy transition process. Overall, TS refers to the trust issues that arose throughout the inquiry process. Frequently referred to TS ideas included:

- *Suggestion to have another public comment period to allow for community feedback on the report prior to the Board of Trustees receiving it in January; via internet (S-THM, F/S-THM, Alumni-THM)*
- *Confusion as to why closing the power plant was NOT part of the plan (S-THM, COM-ER)*
- *How were the potential health impacts associated with different strategies taken into account (S-THM, COM-ER)*

In general, students during the town hall meetings demonstrated a concern for the ways in which health was taken into account during the planning process. It was stated by one student during a town hall meeting:

"*I also don't want to see asthma increase or birth defects so I am still failing to see how the committee is taking health into account*" (Student-THM 9-21-11 pg 5).

The students did not agree that the vision of 100% renewable energy sources can be achieved without clearly stated goal to retire the power plant.

"*How can the vision to reach 100% renewable be reflected if retiring the coal plant is not in the plan?*" (Student-THM 9-21-11 pg 1).

Summary of Feedback

The administration population discussed the least amount of themes. Yet, this group was prescriptive with their institutional suggestions. For example, suggestions were made to expand MSU's outreach mission and allow for a broader outreach process to occur to continue to reflect the university goal to educate the public and bring them on board with the universi ty's activities. The administration population also felt there was potential in sociological approaches to raise awareness and therefore, instill a commitment among energy users to utilize energy and space more sustainably.

Alumni population was similar, and did not discuss many different themes. However, they presented clear ideas which demonstrated an appreciation for the complexity of MSU's energy issues. This group was positive in nature and suggested examples of potential funding schemes and fee structures; collaboration schemes and suggested to include transportation in the campus emission calculations. Although there were few alumni involved in the outreach process, they collectively suggested that broad collaboration through an organized campaign may be a great way to increase the support (financial and social) for MSU's Energy Transition Plan.

The community population demonstrated a general understanding of both supply and demand issues and also pointed out various relationships between cost thresholds and strategies (i.e. the timeline of a renewable energy project and the associated costs). A common message community members involved in the outreach process presented was the importance of collaboration and transparency throughout the planning and implementation process. Furthermore, the community suggested that more outreach opportunities be available in the future which would continue to encourage collaboration with the broader community (i.e. local NGO's).

Faculty and staff spoke about a wide range of key themes and tended to be more prescriptive about their suggestions clearly because of their understanding of the current campus energy system infrastructure, institutional arrangements and energy challenges. MSU faculty and staff acknowledged the traditional university framework may be presented with a different paradigm in the coming years regarding university growth and the overarching sustainability. Furthermore, it was suggested to push ourselves to continue utilizing our resources and skills to reflect our values of becoming a green institution. To encourage such innovation many faculty and staff supported collective behavior changes, while also incorporating an energy/space fee on end users, or economic incentives to aid in the conservation and maintainability of the energy transition plan.

The student population was less aware of the limiting institutional arrangements (which for purpose of this project is defined as the policies, unspoken agreements, social norms, systems and processes that MSU uses to legislate, plan and manage their activities efficiently and effectively). The students spoke about the widest array of key themes compared to other participants and stressed the urgency to have more aggressive goals which happen sooner rather than later. Common among students was the institutional suggestion (INS), which is defined as a process, systems thinking, socially accepted norm etc. that manages, plans, or regulates activities within a system. Retiring the T.B. Simon power plant and the addition of a percent coal reduction goal were two of the rather specific suggestions the students suggested should be added to the Energy Transition report. A general lack of knowledge regarding MSU's energy system and boundaries was suggested to be a challenge therefore limiting students understanding of how they can make an impact and what the outcomes of their impacts might be.

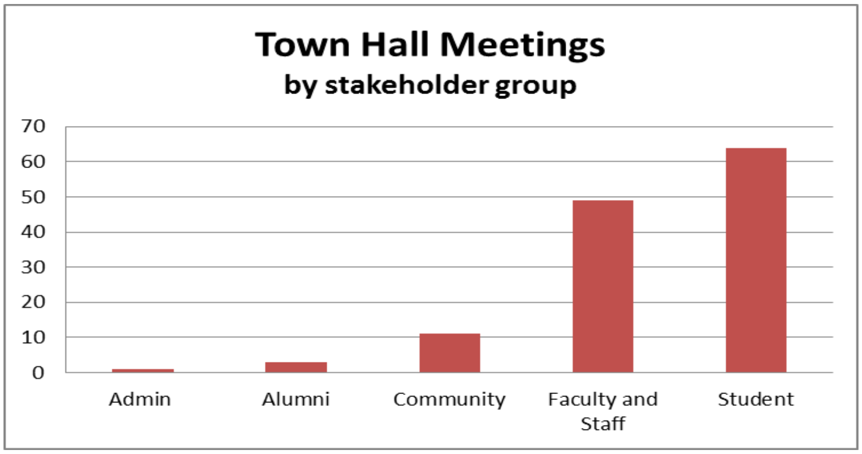
Appendix I

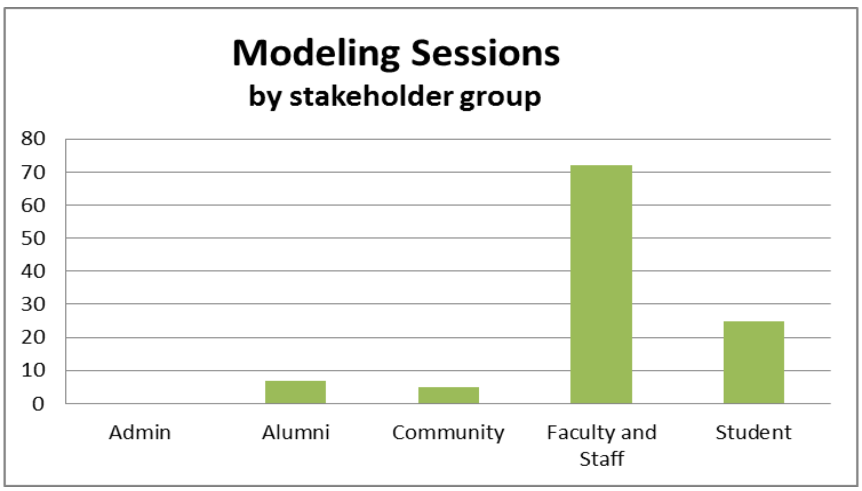
Table 3 List of Abbreviations

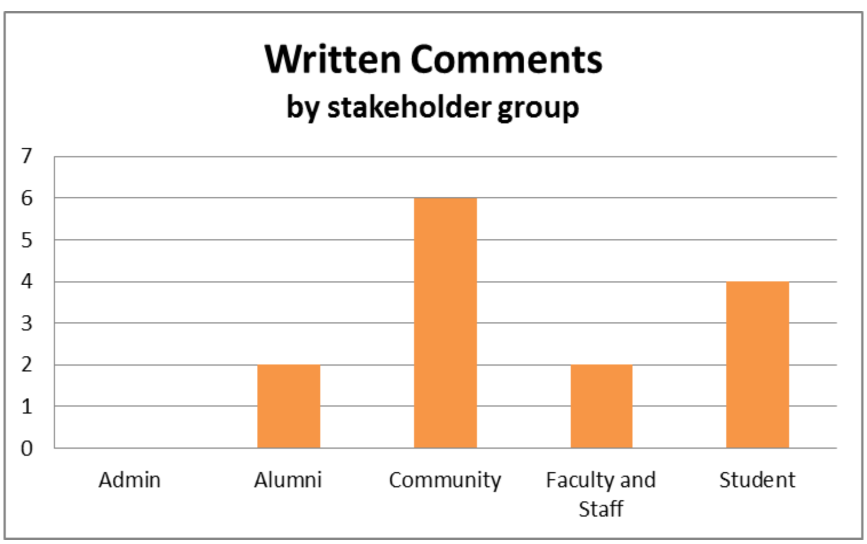
Abbreviation	Expanded version
THM	Town Hall Meetings
ER	E-mail Response
S	Student
ADMIN	Administration
COM	Community
F/S	Faculty and/or Staff

Appendix II

Table 4 Sample sizes for data collection phases







Appendix III

Table 5 suggested participant sample sizes for each stakeholder group for all outreach activities, with a confidence interval of 20

Stakeholder Group	Sample Size (Min. to Max.)	Collected
Administrative	1-5	1
Alumni	3-11	12
Community	5-24	22
Faculty and Staff (F/S)	5-24	123
Students	5-24	93
TOTAL	28-131	251

Population:

- **Student's total**: 47,131
  - Undergraduates: 36,058
  - Graduates: 11,073
- **Faculty** and **Staff**: 11,100
  - Faculty: 4,900
  - Staff: 6,200
- **Administrative members**: 19
- **Living Alumni**: 480,000
  - *Source*: www.msu.edu/about/thisismsu/facts.html
- **Community:**
  - **East Lansing residents**: 48,579
  - **Lansing residents**: 114,297
    - *Source*: 2010 census

Appendix IV

Table 6: Feedback Topics

Key theme	Definition
Behavior Influence (BI)	Refers to a comment regarding the potential impact individuals, education, outreach or lack thereof any of the just listed (or not listed) categories may have on net energy consumption on campus. Also, including comments regarding individuals actions that may impact energy use on a building, department, or unit level
Building Criteria (BC)	Refers to comments about certain building regulations such as the LEED program or net zero emission producing buildings; a criteria for new and additional building construction
Campus Growth Patterns (CG)	Refers to comments that are made to suggestion an alteration to the current way campus grows annually; therefore to make an impact on energy use
Capacity (K)	Refers to a comment regarding the power and energy available to meet the needs of the campus at any particular time
Centralized System (CS)	Refers to a comment that stakeholder(s) have which support a more centralized organizational utility structure
Clean Energy Technology (CET)	Applies to any comment made referring to the need for clean, zero emission technologies including carbon sequestration technology, and carbon capture in the general sense. These suggestions may also include: solar, wind or geothermal options etc.
Close Power Plant (CPP)	Refers to the idea that if it costs (economically, socially, and/or environmentally) to keep the power plant up and running it would make more sense to shut down the plant and purchase electricity elsewhere (i.e. retire the coal plant)
Consumer Behavior (CB)	Refers to belief that people can change their behaviors-perspectives-beliefs and therefore influence the amount of energy consumed in their community-building-dorm; referring to the potential lever consumer behavior can play in regulating the energy trajectory overtime
Cost (C)	Reference to financial concerns in a wide range of issues. Such as the tipping points for tuition, room & board, energy costs, suggestions for economic limitations (i.e. state limiting tuitions increases and other financial limitations etc.)
Distributed Systems (DS)	Refers to a comment that stakeholders have which support a more decentralized organizational utility structure. These comments can be either in support or opposition to distributed/decentralized system.
Emission Inclusion (EI)	Comments/questions regarding how emissions are calculated, what variables are accounted for what are the units of measurement and what is already being calculated/accounted for
Emission Reductions (ER)	Perspective that there needs to be a measurable reduction in GHG's, SOX, NOX etc. different than what is already listed in the plan
Energy Consumption (EC)	Applies to any comment referring to stories about current energy consumption behaviors, technologies used and self regulating policies or institutional arrangements
Flexibility (Flex)	Refers to comments regarding the strategies impact on campus's resiliency in terms of capacity, reliability and cost (i.e. need to keep options on the table to deal with unforeseen future legislature or other issues)

Fuel Switching (FS)	Reference to need to change the types of fuel sources be used on campus including both renewable and non-renewable fuel type options, discussing pros and cons about each type of fuels
Green Reputation (GR)	Any comments regarding the idea that a renewable energy portfolio for MSU will provide social, economic and/or cultural capital, added benefit to the university
Health Concerns (HC)	Comments that include internal and external (to the campus) factors that influence the well-being of community members and greater environment (aggregated, assuming the standard case-risk assessment thinking) as assumed to be associated with energy production and consumption activities
Information about Energy Use (EU)	Comments that include the provision for a regular feedback on the energy consumed by the end users at MSU and updates about how the university is meeting its conservation goals, in addition references to training for incoming members and students to the campus
Infrastructure Suggestions (IS)	Applies when an idea or comment is recommended referring to a specific-known alternative technology or idea that is believed to be currently available to add to infrastructure on campus to help achieve vision (i.e. load shifting, small modular incinerator etc.)
Institutional Suggestion (INS)	Refers to suggestions made that includes larger process ideas that stakeholders have that they think would further develop the strategies and goals set forth by the steering committee (i.e. funding structure, insert into policy context, collaborate with NGO's etc.)
New or Increases to Existing Fee's (F)	Refers to comments that are described as a per semester fee levied on all students, faculty/staff, or building/unit fees on the energy end users/consumers/purchasers; and or a fee on energy use per unit/building etc.
Off-Site Energy (OE)	Refers to any off-campus energy source that can contribute to MSU's meeting and sustaining its energy requirements
Prioritizing (PP)	Refers to the belief that a strategy should be to prioritize high intensity buildings to be the first projects tackled, therefore larger projects should be first concern of the Energy transition process
Reliability (R)	Refers to a perspective regarding the campus's ability to provide uninterrupted utility services (steam and electricity), or opposite changing the reliability of campus energy supply
Target (T)	Applies to a suggestion for what the energy strategies should include in the future (near term long term) (i.e. emission reduction and renewable energy goals or activities etc.) These suggestions are specific, exact, tangible or measurable ones.
Transparency (TS)	Refers to a comment that is made regarding how a process is executed, how participation of public is taken into account, overall what are the trust issues stakeholders may have related to general public feedback and committee process
Urgency (U)	Refers to the concern that goals for (renewable & emissions) need to take place sooner rather than later, and/or be more aggressive

Appendix V

Table 7: Feedback Topics by Stakeholder group

Faculty/Staff Topics	Frequency	% of comments
(INS) Institutional Suggestion: suggestion, regarding systems thinking process element of plan or committee	29	43.3%
(IS) Infrastructure Suggestion: Adopt structural technologies, materials etc.	8	11.9%
(C) Cost: Concern regarding cost	5	7.5%
(CET) Clean Energy Technology: renewable energy technology onto campus	5	7.5%
(TS) Transparency: General trust	5	7.5%
(CB) Consumer Behavior: sociological impacts that may eventual lead to cultural changes & Energy consumption behaviors	4	6.0%
(CG) Campus Growth: growth paradigms	4	6.0%
(EI) Emission Inclusion: What's included in emission calculations	3	4.5%
(F) Fee: Suggestion to have a fee structure help pay for the activities and strategies	2	3.0%
(K) Capacity: Comment regarding ability to 100% of the time meet energy demand	2	3.0%

Student Topics	Frequency	% of comments
(INS) Institutional Suggestion: suggestion, regarding systems thinking process element of plan or committee	27	32.9%
(TS) Transparency: General trust	8	9.8%
(C) Cost: Concern regarding cost	5	6.1%
(U) Urgency: Must take action sooner rather than later	5	6.1%
(IS) Infrastructure Suggestion: Adopt structural technologies, materials etc.	5	6.1%
(GR) Green Reputation: recognition	4	4.9%
(HC) Health Concern: internalize health impacts into cost	4	4.9%

(T) Target: envision different philosophy, goal, strategies etc.	4	4.9%
(CET) Clean Energy Technology: renewable energy technology onto campus	3	3.7%
(BI) Behavior Influences: potential impact individuals, education, outreach or lack thereof any	2	2.4%
(CS) Centralized System	2	2.4%
(EU) Information about Energy Use:	2	2.4%
(ER Emission Reduction	2	2.4%
(EI) Emission Inclusion: What's included in emission calculations	2	2.4%
(BC) Building Criteria: LEED or zero emission buildings	1	1.2%
(CPP) Close Power Plant: shut down the current plant	1	1.2%
(DS) Distributed Systems: decentralized energy structure	1	1.2%
(EC) Energy Consumption: behavior and technology	1	1.2%
(FLEX) Flexibility: impact on campus resiliency	1	1.2%
(FS) Fuel Switching: change the types of fuel used at the power plant	1	1.2%
(PP) Prioritizing: strategies should focus on high energy users	1	1.2%

Alumni Topics	**Frequency**	**% of comments**
(INS) Institutional Suggestion: suggestion, regarding systems thinking process element of plan or committee	7	41.2%
(TS) Transparency: General trust	5	29.4%
(HC) Health Concern: internalize health impacts into cost	2	11.8%
(EI) Emission Inclusion: What's included in emission calculations	1	5.9%
(U) Urgency: Must take action sooner rather than later	1	5.9%
(CPP) Close Power Plant: Include in plan that the coal plant will be retired	1	5.9%

Community Topics	**Frequency**	**% of**

		Comments
(INS) Institutional Suggestion: suggestion, regarding systems thinking process element of plan or committee	19	45.2%
(TS) Transparency: General trust	5	11.9%
(CET) Clean Energy Technology: renewable energy technology onto campus	4	9.5%
(C) Cost: Concern regarding cost	3	7.1%
(HC) Health Concern: internalize health impacts into cost	3	7.1%
(IS) Infrastructure Suggestion: Adopt structural technologies, materials etc.	2	4.8%
(FS) Fuel Switching: Burn less coal more natural gas and other more renewable and less carbon producing material i.e. biomass	2	4.8%
(BI) Behavior Influences: potential impact individuals, education, outreach or lack thereof any	2	4.8%
(CPP) Close Power Plant	2	4.8%

Administration Topics	Frequency	% of Comments
(INS) Institutional Suggestion: suggestion, regarding systems thinking process element of plan or committee	7	77.8%
(IS) Infrastructure Suggestion: Adopt structural technologies, materials etc.	1	11.1%
(FS) Fuel Switching: Burn less coal more natural gas and other more renewable and less carbon producing material i.e. biomass	1	11.1%

Appendix VI

Articles published about MSU Energy Transition Plan

1. Campus Sustainability Day forum. (2010, October 15). *Michigan State University News,* pp. online.
2. MSU marks Campus Sustainability Day. (2010, October 18). *Michigan State University News*, pp. online.
3. Hubbard, Shawn. Hubbard: Become more educated about our energy issues. (2010, December 12). *Lansing State Journal,* pp. unknown.
4. Energy transition moving forward at MSU. (2011 January 27). *Michigan State University News*, pp. online.
5. Durisin, Megan. Renewable energy to be focus of new transitional plan. (2011, January 31). *The State News*, pp. 3.
6. Spork, Meghan. Staff Profiles: Lynda Boomer. (2011, March 10). *Michigan State University News*, pp. online.
7. Ballentine, Summer. Council discusses energy plan. (2011, March 22). *The State News*, pp. 1.
8. Ballentine, Summer & Durisin, Megan. Round the clock, University staff work to make city-sized MSU operate smoothly 24.7. (2011, March 25). *The State News*, pp. 1, 2.
9. MSU kicks off Earth Month with weekly 'Dim Down'. (2011, March 28). *Michigan State University News*, pp. online.
10. Steering Committee to guide MSU energy transition. (2011, March 28). *Michigan State University News*, pp. online.
11. Committee seeks ideas for future energy system. (2011, April 15). *Michigan State University News*, pp. online.
12. MSU receives STARS silver rating for sustainability achievements. (2011, April 28). *Michigan State University News,* pp. online.
13. MSU sees significant energy reduction from Earth Month program. (2011, May 27). *Michigan State University News*, pp. online.
14. Energy Transition Steering Committee to host town halls this fall. (2011, August 25). *Michigan State University News*, pp. online.
15. Groppe, Maureen. Power struggles: New regulations to protect environment raise economic concerns. (2011, August 30). *Lansing State Journal,* pp. 1A.
16. Next MSU energy transition town hall set for Sept. 21. (2011, September 19). *Michigan State University News,* pp. online.
17. MSU students seek end to campus coal plant. (2011, October 19). *MichiganNow.org*, pp. online.
18. Ryan, Rebecca. Flash Mob Begins Protest. (2011, October 20). *The State News*, pp. 5.
19. Wittrock, Angela. Report: Three MSU students arrested for coal plant protest, refused to leave building. (2011, October 21). *MLive.com*, pp. online.
20. Heywood, Todd. Student activists arrested during sit-in of MSU president's office. (2011, October 21). *Michigan Messenger,* pp. online.
21. Schreiber, Dan. Student activists at Michigan State University risk arrest to quit coal. (2011, October 21). *Greenpeace USA,* pp. online.
22. Protest right move, must lead to action. (2011, October 26). *The State News*, pp. 4.
23. Hayhoe, Beau. Calculating Consumption. (2011, October 27). *The State News*, pp. 1, 2.

24. Zylinski, Cassie. Energy committee's process flawed. (2011, October 31). *The State News*, pp. 4.
25. Wong, Tori. MSU's coal use affects well-being. (2011, November 4). *The State News,* pp. 4.
26. MSU should continue work toward no coal. (2011, November 14). *The State News,* pp. 4.

Energy Transition Plan
External Advisory Committee Summary

In order to assist the Steering Committee in creating a well thought out Energy Transition Plan, the MSU Administration sought external opinions on the proposed goals and strategies from those with experience in energy planning for higher education, energy regulation, and renewable energy technology and markets. The following individuals agreed to serve on an external advisory committee and provided valuable feedback to the Energy Transition Plan Steering Committee:

- **Amy Van Kolken Banister, Senior Director, Air Programs, Waste Management Inc.** Ms. Bannister has more than twenty years of experience in air quality consulting, project management, regulation development and planning, as well as air emissions trading and corporate environmental program implementation. Based in Houston, she is currently responsible for directing air quality, GHG emissions and landfill gas program activities at Waste Management, which includes supervising corporate climate change initiatives, developing corporate policies and standards, and developing training programs for application at Waste Management North American facilities.
- **Michael J. Walsh, former Executive Vice President of the Chicago Climate Exchange.** Mr. Walsh oversaw new product research and development and policy analysis for the former Chicago Climate Exchange (CCX), the world's first and North America's only legally binding, rules-based greenhouse gas emissions allowance trading system for all six greenhouse gases. Walsh has played a lead role in the implementation of all major Chicago Climate Exchange initiatives in the U.S. and internationally.
- **Joseph Stagner, Executive Director, Stanford Department of Sustainability and Energy Management.** Mr. Stagner is a registered professional engineer with over 30 years experience in facilities management. He has served as Executive Director of Sustainability and Energy Management at Stanford University since November 2007, where he is responsible for advancing sustainability in campus operations through the interdisciplinary Sustainable Stanford initiative and direct leadership of the university's utility and transportation programs.
- **Fahmida Ahmed, Director, Office of Sustainability, Stanford University.** Ms. Ahmed directs the Office of Sustainability and the campus program Sustainable Stanford (sustainable.stanford.edu). She designs and implements sustainability programs, supports long-term energy infrastructure planning, directs the office's education and outreach efforts, chairs the Sustainability Working Group, and connects the Working Teams.

The External Advisory Committee received the Energy Transition Steering Committee charge, the Black and Veatch Report on Next Generation Energy Strategies and a summary of the draft goals and strategies proposed by the Steering Committee.

The External Advisory Committee convened via conference call to ask questions about the Energy Transition planning process and the background materials received. In addition the members offered suggestions. More formal feedback was solicited through a follow up questionnaire.

A summary of key themes from the conference call and questionnaire comments are listed below.

Planning Process

- Long term horizon for capital planning, campus stakeholder engagement, educational component for campus community as the plan moves though stages and approval. Start with the end vision in mind, even though every plan has its limitations. These criteria are meant to be balanced and optimization criteria, not necessarily limiting factors.
- It is difficult to determine from our seats if the goals are too high or too low, however the process to determine the targets seems sound. The key is to choose targets that are feasible, which may not be popular.

Regulatory Considerations

- The committee should be aware that the Boiler MACT Rule and the Commercial/Industrial Solid Waste Incinerator MACT are being reconsidered.
- The EPA will likely publish revisions to the non-hazardous secondary material rule (NHSM). The NHSM Rule defines what a solid waste is and for purposes of Boiler and CISWI MACT Rule applicability. For example, "Urban Wood Waste," which T.B. Simon Power Plant is currently permitted to burn in Boiler #4 and is seeking permit authority to burn in all boilers, may not be considered a fuel by NHSM Rule definition. If Urban Wood Waste is by definition a waste and not a fuel, then the boilers would be considered "incinerators" and subject to CISWI Rule, not Boiler MACT requirements.

Demand Side Strategies

- The maximum gain from pushing energy bills down in the university to end users would be realized if that transition process is aided through hand-holding and incentives/rewards to energy savings successes.
- Campus behavior is important – it increases institutional awareness which helps reduce consumption.

Supply Side Strategies

- In the short term, processed or engineered fuel technology currently exists to displace coal dependency. The fuel specification can be customized to meet BTU and emission/sustainability needs. There may be opportunity to use feedstock generated on campus, thereby avoiding disposal costs of material.
- Anaerobic digestion is also existing technology that uses yard, food and animal waste as feedstock. There may be opportunity to expand upon your current pilot project and use renewable fuel (biogas) in the boilers. Harvest Power operates composting, biogas and syngas operations and we are working with them to develop high-solids aerobic and anaerobic digestion and composting technologies, which accelerate the decomposition or organic materials to produce renewable energy. If technically feasible, there may be opportunities to make such projects financially feasible as well. To manage costs, public/private partnerships may be a solution.
- Geothermal energy should be considered at MSU.
- Combined Heating & Cooling (CHC, aka heat recovery- but not the same as Ground Source Heat Exchange) may be more economically and environmentally attractive than Combined Heating & Power (CHP, aka Cogeneration).

MICHIGAN STATE UNIVERSITY

Energy Transition Plan

energytransition.msu.edu